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TECHNICAL
REPORT

Demonstration of Lead-Based Paint Removal and Chemical Stabilization Using Blastox®

by
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13. ABSTRACT (Maximum 200 words)

The U.S. Army maintains a large inventory of buildings treated with lead-based paint (LBP). LBP abatement and disposal is problematic. The residual waste from LBP removal often contains enough lead to be considered a hazardous waste, thereby requiring special handling and disposal. Associated higher costs of worker protection and waste disposal prohibit the use of traditional paint removal methods for removing LBP.

A recently developed proprietary product—Blastox®—consists of a material, which, when added to a typical abrasive medium, creates an "engineered abrasive" that is suitable for removal of lead-based paint systems from most surfaces and that, when water is added, also chemically stabilizes the lead in the residual waste so that the waste does not exhibit the Resource Conservation and Recovery Act (RCRA) toxicity characteristic for lead.

This investigation evaluated the performance and cost-effectiveness of using Blastox® for removing LBP from wood and steel structures, and for stabilizing the residual waste material. Both laboratory and field evaluations confirmed the feasibility and cost-effectiveness of using Blastox to remove and stabilize LBP.

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Executive Summary

The U.S. Army maintains a large inventory of buildings constructed prior to 1978. Since the likelihood that lead-based paint (LBP) will be found increases with the age of the building, these buildings may have lead-based paint on some surfaces. Some of these buildings are slated for demolition and disposal, and others require paint removal during maintenance and repair or renovation activities, or where a lead-based paint hazard cannot be successfully controlled through management-in-place techniques.

This study evaluated the performance and cost-effectiveness of using Blastox® for LBP removal from wood and steel structures, and to measure the characteristics of the residual waste material. Laboratory analyses showed that Blastox® is a calcium silicate-based material; its stabilization mechanisms should be similar to those of Portland cement. Chemical substitution reactions and physical encapsulation of the waste are the two stabilization mechanisms that provide a matrix with excellent long-term stability characteristics.

A laboratory and field evaluation of lead-based paint removal using abrasive blast media combined with the proprietary lead stabilizer as part of an engineered abrasive confirmed the feasibility of removing and stabilizing lead-based paint waste. The process performed well in field demonstrations on both wood and steel substrates. Abrasive blasting successfully removed the paint while the lead stabilizer immobilized the lead, allowing the waste to pass the USEPA Toxicity Characteristic Leaching Procedure test. The use of a chemical stabilizer combined with an abrasive blast medium was shown to be cost effective based on a hazardous waste disposal cost avoidance of \$0.12 to \$0.43 / sq ft of abated surface for wood substrates and \$0.93 to \$3.04 / sq ft for steel substrates.

Foreword

This study was conducted for U.S. Army Center for Public Works (USACPW) under the Facilities Engineering Application Program (FEAP); Work Unit M3-FE3, "Deleading of Wooden Structures and Building Components," and Work Units FEAP-M3-F83 and FEAP-FM-F74, "Deleading of Elevated Steel Water Tanks," and USACPW reimbursable funding document RP222-OM-G83, "Abrasive Blasting of Lead Using Hazardous Waste Stabilizers." The technical monitors were Charles Racine, CECPW-EB and Malcolm McLeod, CECPW-ES.

The work was performed by the Engineering and Materials Division (FM) of the Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigators were Vincent Hock and MAJ Lewis Setliff. The contributions of the following USACERL personnel are gratefully acknowledged: Lake Lattimore, Ali Odeh, Scott Covey, and Dr. Ashok Kumar. Julie Emery and Patricia Kemme at the USACERL Environmental Chemistry Laboratory provided invaluable analytical support. Co-author Curt Gustafson is now Manager of New Product Development at The TDJ Group, Inc., Cary, IL. The technical assistance provided by Bryan Nix, Steve Hopkins, and Michael Worsham, Assistant Chief of Staff for Installation Management (ACSIM), and Dr. Charles Lozar, a consultant and director of Architects Equities Research Group, Champaign, IL, was essential to the successful completion of this work. Invaluable on-site technical and logistical assistance was provided by the following personnel: Serag Wahba, ANME-PWP-E, Paul Robert, Jr. and Sara Gracey, ANME-PWE, Fort Meade, MD; Nick Pallotto, Fort Carson, CO; and Robert Erwin, Fort Hood, TX. Dr. Ilker R. Adiguzel is Acting Chief, CECER-FL-M, and Donald F. Fournier is Acting Operations Chief. The USACERL technical editor was William J. Wolfe, Technical Resources Center.

COL James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

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1 Introduction

Background

The U.S. Army maintains a large inventory of buildings constructed before 1978, when lead-based paint (LBP) was prohibited from sale to the general consumer and was banned from use on residential structures and on consumer items such as toys and furniture (40 CFR 240-280). The Army also owns over 300 elevated water storage tanks and hundreds of other steel structures (bridges, equipment, and buildings) that have been painted with red lead primers.

The likelihood that any particular building will contain LBP increases with the structure's age, a circumstance that complicates required maintenance or demolition of older buildings—the most likely candidates for such treatment. For example, in residential structures or other facilities where children are present, LBP must be removed where an LBP hazard cannot be successfully controlled through management-in-place techniques. Other buildings require paint removal during regular maintenance and repair or renovation activities. While the Department of Defense (DOD) has scheduled some of its older buildings for demolition and disposal, it has been unable to proceed with this needed action because of the higher costs associated with the disposal of LBP-painted building components.

Regardless of whether LBP has been applied to a substrate of steel or wood, LBP abatement and disposal is problematic. The U.S. Environmental Protection Agency (USEPA) Resource Conservation and Recovery Act (RCRA) classifies any waste that leaches 5 parts per million (ppm) or more of lead (as determined by the USEPA toxicity characteristic leaching procedure [TCLP EPA Method 1311, 1990] test) a *hazardous waste*, which requires special handling and disposal (14 CFR 1303). Since the residual waste from LBP removal commonly falls into this category, the high costs of worker protection and waste containment and disposal prohibit the use of traditional paint removal methods (chemical stripping and abrasive blasting) for removing LBP.

A recently developed proprietary product—Blastox®—consists of a material* that may be added at a rate of 20 weight percent for removing paint from steel or 25 weight percent for wood to a typical abrasive medium (such as coal slag or silica sand) to create an "engineered abrasive" suitable for sand-blasting lead-coating systems from wood, steel, or concrete surfaces. The manufacturer maintains that the additive chemically stabilizes the lead in the residual waste so that it will leach lead at a rate less than 5 ppm, not exhibiting the RCRA toxicity characteristic for lead. This investigation was undertaken to determine whether the use of this engineered abrasive is feasible for LBP abatement within the DOD.

Objective

The objectives of this study were to evaluate the performance and cost-effectiveness of using Blastox® for LBP removal from wood and steel structures, and to measure the characteristics of the residual waste material.

Approach

Laboratory and field studies were conducted to determine the composition of Blastox®, the kinetics of its reaction with lead compounds, and the chemical stability of the reaction products. The composition and morphology of Blastox® were determined using scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), x-ray diffraction (XRD), and x-ray fluorescence (XRF). The chemical reactions and the effects of pH were determined by wet chemical analysis. The leaching characteristics were determined by TCLP, multiple TCLP, and multiple extraction procedure (MEP USEPA Method 1320, 1989) analyses.

The engineered abrasive was field tested at Fort Meade, MD, Fort Carson, CO, and Fort Hood, TX, where Blastox®-modified abrasives were used to remove LBP from wood and steel surfaces. The field tests included environmental monitoring of site and personal air, XRF on the substrate before and after paint removal, and TCLP analysis of the waste product. A cost-benefit analysis was done to determine the economic feasibility of widespread application of the Blastox® engineered abrasive as a chemical stabilizer. At the conclusion of this research, the findings were submitted to the USEPA Office of Solid Waste and Emergency Response.

* Blastox® is a product of the TDJ Group, Inc., 760-A Industrial Dr., Cary, IL 60013, tel. 847/639-1113.

Mode of Technology Transfer

FEAP User Guides and Ad Flyers will be published describing the use of engineered abrasives to remove LBP from steel and wood surfaces. It is recommended that the Draft Corps of Engineers Guide Specification CEGS 02090, *Lead-Based Paint (LBP) Abatement and Disposal*, be updated to include the use of tested and proven engineered abrasives such as Blastox®.

Metric Conversion Factors

A table of metric conversion factors for U.S. standard units of measure used throughout this report is presented below.

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 sq ft	=	0.093 m^2
1 sq ft/min	=	0.093 m^2/min
1 cu ft	=	0.028 m^3
1 mi	=	1.61 km
1 lb	=	0.453 kg
1 gal	=	3.78 L
1 psi	=	6.89 kPa
1 µm	=	1×10^{-6} m
°F	=	(°C × 1.8) + 32

2 Strategies for Removal/Stabilization

The Costs of LBP Removal

Four areas of the LBP removal process must be considered when developing a strategy to minimize removal costs:

1. *Containment*: All removal processes demand some type of containment under USEPA regulations so that the environment is not contaminated. The level of containment necessary varies with each process and the constraints at each site. The removal process may generate lead-contaminated dust, debris, or fluid wastes that must be contained and collected for proper disposal.

2. *Labor*: All removal processes require labor; however, the amount and the training necessary for the workers varies with each process. Some processes are labor-intensive and some require special training for the workers to handle special chemicals, equipment, or lead dust, for example.

3. *Materials*: Every process has material costs, whether for abrasive media, chemicals, or special tools or equipment. If special tools are required, then there is a high initial cost, but these costs may be justified if the other costs are minimized by the process.

4. *Disposal*: Every process generates waste such as paint chips, abrasive media, or chemical stripper wastes, and contaminated articles such as plastic sheeting from containment structures. The cost of disposal is determined by the volume and the hazardousness of the debris. A large volume may by disposed of cheaply if it is not hazardous; disposal costs of a hazardous material are very significant. According to the RCRA, special permits may be required to transport and treat hazardous wastes generated by LBP removal. These permits take time and money to obtain.

Conventional Abrasive Blasting

Abrasive blasting is a process in which abrasive particles, such as sand, steel shot, plastic beads, or coal slag are propelled at the structure's surface. The propelling medium is usually compressed air. As the particles strike the surface, they abrade the paint from the substrate. (If the substrate is wood, the top layer of the substrate is also removed. The amount removed depends on the type of wood and its condition, type of abrasive, particle morphology, and air pressure.) The debris is usually collected on a tarpaulin laid on the ground or scaffolding beneath the work. Once the paint is removed, the surface is sanded to the desired finish, then recoated. On steel substrates, the only restriction is that the surface must be primed soon after blasting to prevent flash rusting.

The advantages of using abrasive blasting to remove LBP are that:

1. It completely removes all the LBP from the surface.
2. It has a fast removal rate (about 100-150 sq ft/hour on wood and steel surfaces).
3. The materials used for the process are inexpensive.

The disadvantages of using abrasive blasting to remove LBP are that:

1. The process creates a large volume of waste.
2. The waste is usually classified as hazardous and must be disposed of accordingly.
3 Containment structures are needed due to the significant amount of dust created.
4 The initial capital costs can be significant due to the equipment requirement.
5. It may destroy soft substrates and damage even hard ones.

Blasting With Engineered Abrasives

High production rates, good surface profile, and a surface amenable to subsequent surface coating can all be achieved through abrasive blasting with a variety of blasting media. A traditional abrasive can be modified (engineered) by adding a sulfate, silicate, or phosphate-based material. When water is added, the engineered abrasive will then react with the lead paint particles to reduce lead leachability, and the waste will not exhibit the RCRA toxicity characteristic for lead.

However, sulfate and phosphate additives can cause problems with the performance of subsequently applied coatings. Thus one of the major disadvantages of the conventional abrasives is eliminated. Other disadvantages remain:

1. There is still a large volume of waste.
2 Containment structures are still required.
3. The initial capital costs are the same as conventional abrasives.
4. If used improperly, any abrasive may destroy the surface from which the paint is being removed.

3 Development and Laboratory Evaluation

Laboratory Evaluation

The laboratory evaluation of the chemical stabilizer Blastox® engineered to immobilize lead was performed in three phases:

1. The composition and morphology of Blastox® were determined using scanning electron microscopy (SEM), x-ray diffraction (XRD), and x-ray fluorescence (XRF).
2. The mechanism by which Blastox® stabilizes the lead was investigated using energy dispersive spectroscopy (EDS) and wet chemical analysis.
3. The chemical stabilizer durability, i.e., long term stability, was determined by toxicity characteristic leaching procedure (TCLP), multiple TCLP, and the multiple extraction procedure (MEP USEPA Method 1320, 1989) analyses.

Preparation of Samples and Description of Analytical Methods

The first step in this research was to produce a white, lead-based paint similar in composition to that in service on wood structures. A lead-based paint formulation Federal Specification TT-P-104b (1965), was prepared with addition of 0.001 weight percent silica fume to aid the retention of the suspension of the paint. Table 1 gives the paint formulation, without the silica fume.

Table 1. Composition of lead-based paint, Federal Specification TT-P-104b.

Ingredients	By Volume (gal)	By Weight (lb)
Basic carbonate, white lead	0.26	14.20
Refined linseed oil–acid No. 6-8	0.21	1.63
Raw linseed oil	0.21	1.63
Bodied linseed oil, body Z-2	0.10	0.81
Mineral spirits and drier	0.22	1.43
Total	1.00	19.70

The materials were weighed on an analytical balance accurate to ± 0.01 g. Once weighed, the raw materials were placed in a 64-oz polyethylene bottle for further processing. Then, several 1.25 to 2.25 cm diameter alumina balls were added to the matrix and milled for 24 hours to homogenize the paint. The substrates were 12 x 6 x 1-in. pieces of white pine. Either one or two coats of the paint were applied to the surface of the substrates.

The coated substrates were air-dried for 72 hours, then placed in a drying oven at 65 to 80 °C until the coating system was completely dry.

Abrasive Blasting of Samples

Once the samples were prepared, the coating system was removed by abrasive blasting. A blasting cabinet was used for all abrasive blasting. The cabinet was 36 x 18 x 12-in. in size, and was equipped with both front and side doors for easy sample loading. The cabinet also contained a dust collection system with a high efficiency particulate air (HEPA) filter to provide a safe environment for the operator. Air pressures of 85 to 90 psi were used to propel silica sand through the nozzle at the substrates. The dust collection system was allowed to operate for a minimum of 2 minutes after blasting to assure that the lead and silica dust was evacuated from the chamber before removing the blasted samples.

Sample Collection

Waste collected from the blasting cabinet for each test was thoroughly mixed before taking a random 100 gram sample for TCLP analysis. Random duplicate samples also were taken to verify the sample collection procedure and the laboratory testing. The samples were remixed before testing to homogenize the mixture.

Toxicity Characteristic Leaching Procedure

The Toxicity Characteristic Leaching Procedure (TCLP) (USEPA Method 1311) procedure used for all the tests is:

1. Each 100-g homogeneous sample was passed through a 9.5 mm standard sieve. Any portion of the sample that failed to pass through the sieve was crushed or milled to reduce its size until it would pass through the sieve.

2. A 5-g portion of the entire sample was tested to determine the extraction fluid to use:
   - A 5-g sample was weighed into a 250-ml beaker.
   - 96.5 ml of deionized water was added, stirred vigorously for 5 minutes, and the pH of the solution was determined. If the pH was <5.0, then TCLP Extraction Fluid 1 (described below) was used.
   - If the pH was >5.0, then 3.5 ml of 1N HCL was added, and the solution was heated to 50 °C and held for 10 minutes. The solution was then allowed to cool and the pH was remeasured. If the pH was <5.0, then Extraction Fluid 1 was used, but if it was >5.0, then Extraction Fluid 2 (described below) was used.

3. The procedure used to prepare the extraction fluids was:
   - *Extraction Fluid 1*: 5.7 ml of glacial acetic acid and 2.572 grams of NaOH were added to 500 ml of deionized water. The volume was increased to 1000 ml. The pH was 4.93 ± 0.05.
   - *Extraction Fluid 2*: 5.7 ml of glacial acetic acid added to 500 ml of deionized water and the volume was increased to 1000 ml.

4. A 100-g sample was transferred to a 2-L, acid-washed polyethylene bottle. Then 2 L of the prescribed extraction fluid were added.

5. The lid was secured and the bottle was placed into the rotator. The motor was started and the bottle lids were checked to assure there were no leaks.

6. The sample was rotated for 18 ± 2 hours.

7. After the samples were finished rotating, the bottles were removed from the rotator. Then 100 ml of the extraction fluid was removed from the bottle and placed into a 150 ml, acid-washed beaker for digestion.

After extraction in accordance with USEPA Method 1311, the next step was digestion of the solution to prepare it for atomic absorption analysis. The procedure used to digest the samples is USEPA SW896 Method 3010A.

The last step in the TCLP test involved using atomic absorption to determine how much of the heavy metal leached from the solid waste into the extraction fluid in parts per million (ppm). A portion of the fluid was retained so that, if an error occurred during atomic absorption, or if the results were not conclusive, it could be reanalyzed. The solid portion was disposed either as an nonhazardous or hazardous waste depending on the results of the TCLP test (USEPA Method 1311).

Atomic Absorption

Atomic Absorption (AA) was used during the TCLP test to determine the amount of lead dissolved by the solution. A Perkin Elmer 3030B flame furnace atomic absorption spectrometer was used to determine the total amount of lead that leached out of the waste. Before measuring the absorbance of any solution, the spectrometer was checked with standard solutions containing 0, 5, 50, 250, and 500 ppm lead.

X-Ray Diffraction

In preparation for x-ray diffraction (XRD) analysis, all powder samples were milled and sieved to prepare a sample with a particle size of 150 microns or less. This was necessary to maximize the peaks since there were many impurities and subsequent background noise. Then a Rigaku D/MAX-B apparatus was used to analyze all samples. Six iterations were summed at 40 kV by a copper target.

Energy Dispersive Spectroscopy

EDS analysis was conducted on an ISI DS-130 scanning electron microscope for all EDS examinations. The accelerating potential was set at 20 kV and the tilt angle was set for an optimum take-off angle of 30 degrees. The use of the EDS equipment was not intended to produce quantitative data, rather it was used to give an elemental analysis of the material and to give approximate ratios of those elements present.

This type of analysis is available on many scanning electron microscopes. The samples are bombarded with x-rays, which excite electrons within the samples. Then, by evaluating the amount of energy the samples give off due to electrons shifting to a lower energy level, an elemental analysis of the sample can be determined.

Field X-Ray Fluorescence

A field portable x-ray fluorescence (XRF) analyzer was used to determine the amount of lead per surface area in mg/cm^2. The analyzer displays the lead x-ray intensity relative to the intensity of the other interfering radiation. The energy spectrum is stored and computer-analyzed to provide a corrected lead concentration on the substrate surface. A correction factor is necessary due to the difference in back-

ground radiation resulting from different types of substrates, i.e., wood, metal, concrete, etc. The XRF analyzer can detect surface lead concentrations as low as 0.1 mg/cm^2, within an error range of ± 0.3 mg/cm^2.

Chemical Composition

This phase was initiated with x-ray diffraction (XRD) analysis. The pre-blast particles were milled and sieved to prepare a sample with a particle size of 150 microns or less to maximize the intensity of the resulting XRD peaks. The results (Figure 1) show that Blastox® is a combination of tri- and di-calcium silicates. A comparison of Figure 1 to the XRD pattern of Portland cement (Figure 2), shows that the peaks are identical except for the peaks resulting from gypsum (the major peaks between 10 and 25 degrees) in the Portland cement sample. Figure 1 also shows that Blastox® does not contain sulfur compounds, which would cause problems with the performance of subsequently applied coatings.

Laboratory x-ray fluorescence analysis was used to conduct the compositional analysis of the material. The results agree with the x-ray diffraction patterns (Figures 1 and 2), which show Blastox® to be a calcium silicate-based material.

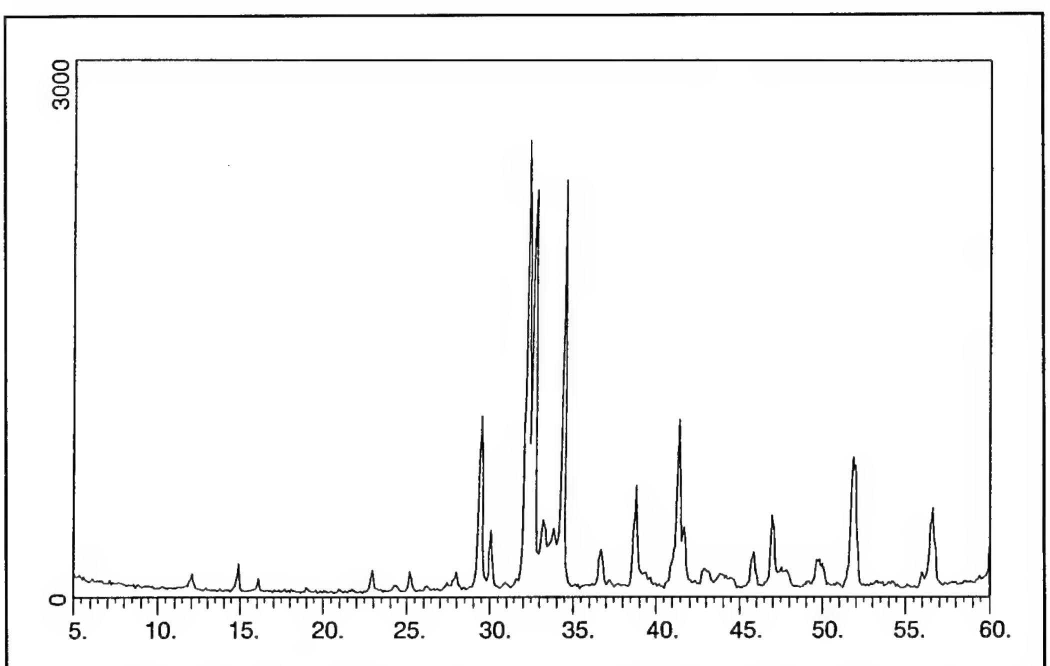

Figure 1. XRD pattern of Blastox®.

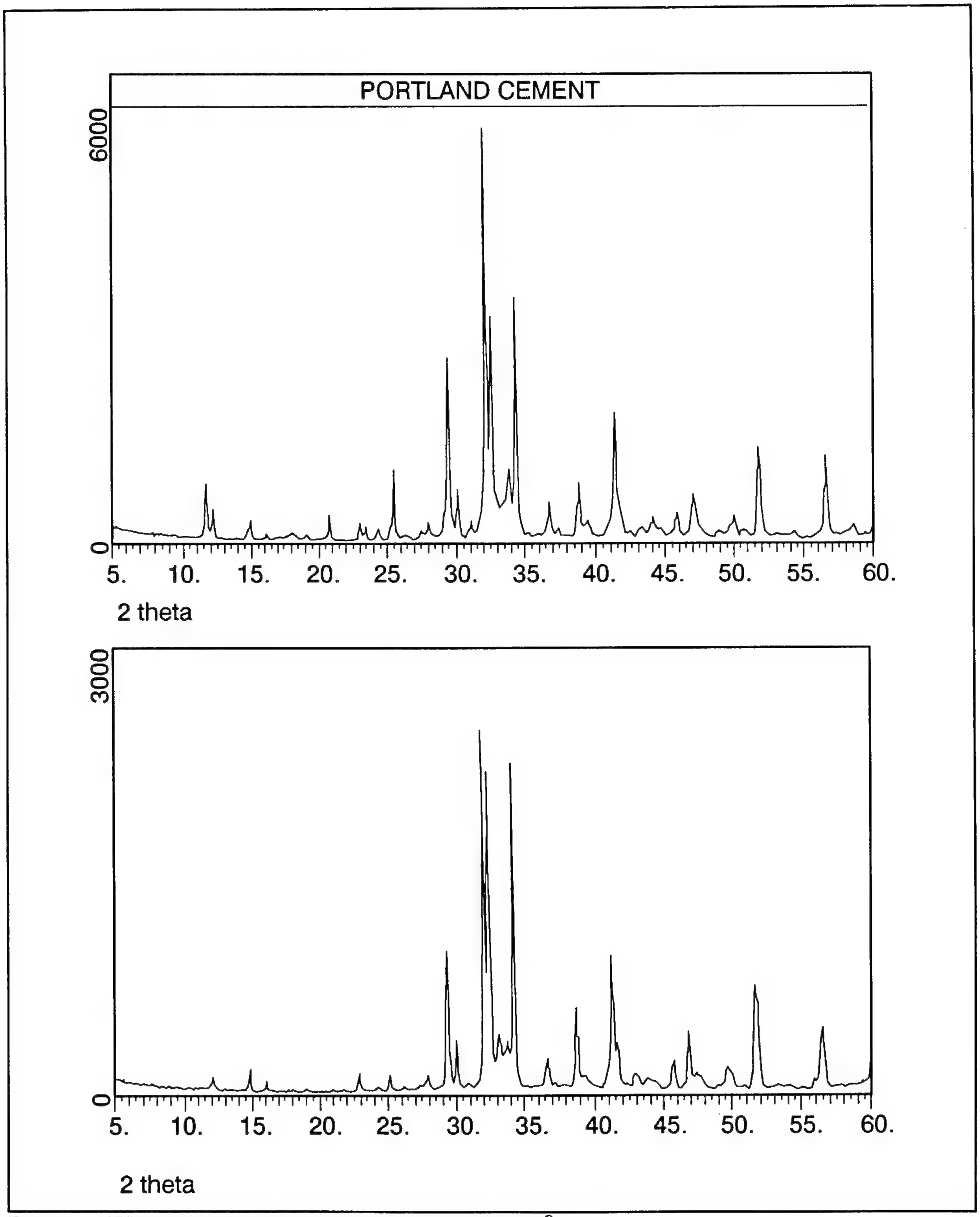

Figure 2. XRD pattern of Portland cement (top) and Blastox®.

Table 2 lists the XRF results of Blastox® and Type I cement (high tri-calcium silicate and high tri-calcium aluminate cements).

Table 2. XRF analysis of Blastox® and Type I cement.

Compound	Blastox® (Wt%)	Type I Cement (Wt%)
CaO	65.52	63.57
SiO_2	22.06	20.89
Al_2O_3	4.58	4.72
MgO	3.55	2.77
Fe_2O_3	2.07	2.25
MnO	0.44	—
K_2O	0.40	0.62
SO_3	0.27	3.10
TiO_2	0.18	0.18
P_2O_5	0.11	—
Na_2O	0.07	0.01

Scanning electron microscopy was used in an attempt to learn more about the structure and particle surface morphology of the chemical additive. The results, shown in Figures 3 and 4, show that the majority of Blastox® is comprised of large crystals (50 microns), with smaller, randomly oriented crystals adhered to the large crystals. The majority of large crystals seem to have the same qualities; e.g., they have the same surface appearance and random orientation, and they appear to have been subjected to preferential crystal growth. This was determined by the high percentage of crystals growing together, and the appearance that some of the crystals were consumed by larger ones. The smaller crystals appear to have a different surface morphology and vastly different shapes. (Figures 3 and 4 show these fiber-like particles mixed in with the other particle shapes). The fibers are bonded to the silicate network and are about one angstrom in length. Note that Figures 3 and 4 show the same area of a particle at two different magnifications to emphasize the diverse particle size, shape, and appearance.

Kinetics

The chemical or physical reactions of lead leaching must occur either during the abrasive blasting operation (dry reactions) or the testing (wet reactions). Thus, the next step was to determine during which stage the lead leaching was reduced. The simplest variable to eliminate from consideration was the dry reactions. The temperatures associated with abrasive blasting paint from a wood substrate are much too low to initiate any reaction between the blast media additive and the lead in the paint. It would take a high level of energy to break both the physical and chemical bonds in the paint matrix, diffuse to the surface of the chips, and then react with the calcium silicate in a dry state.

Figure 3. Scanning electron microscope micrograph of Blastox® (higher magnification).

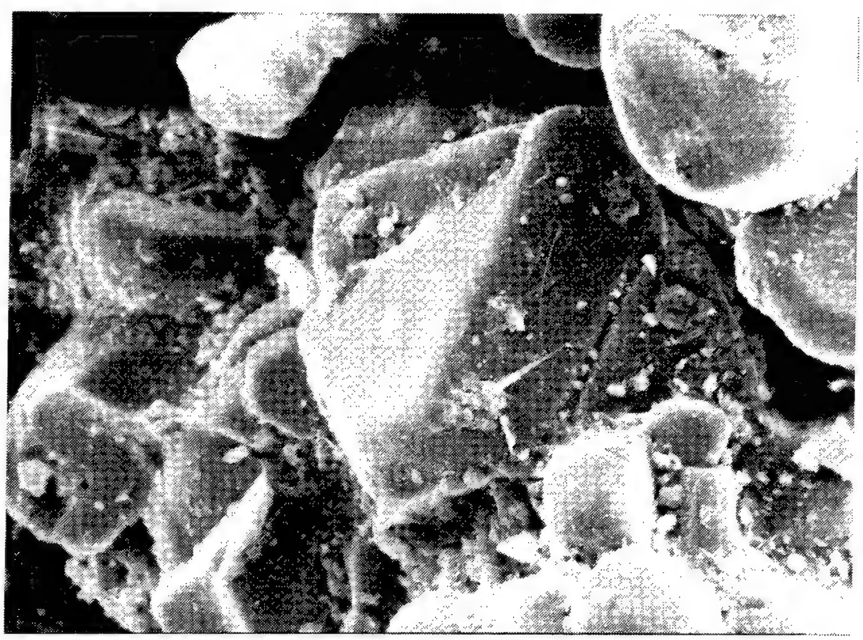

Figure 4. Scanning electron microscope micrograph of Blastox® (lower magnification).

It is highly unlikely that this level of energy is available during blasting; however, a series of tests was devised to validate this hypothesis.

The weight percent distribution in typical spent media/paint matrix is approximately 98 percent spent media and 2 percent paint chips. Based on this, two sets of 100 gram samples were made. The first set consisted of 98 grams of unused blast media with 15 weight percent Blastox®, and two grams of large paint chips. The second set of samples was identical, except that the paint chips and chemical additive were milled separately to simulate the particle size associated with post-blasting. The samples were tested with the TCLP; however, the blast media and paint chips were kept separate until both were placed in the TCLP solution, thus preventing any dry reaction from occurring between the Blastox® and lead. As expected, the lead leachability of these samples was very low (less than 1 ppm).

Both pre- and post-blast Blastox® particles were studied by EDS. Figures 5 and 6 show no lead incorporated into the post-blast Blastox® particles. These slight composition differences of the pre- and post-blast Blastox® particles are normal variations between samples were analyzed at different times. These data do not

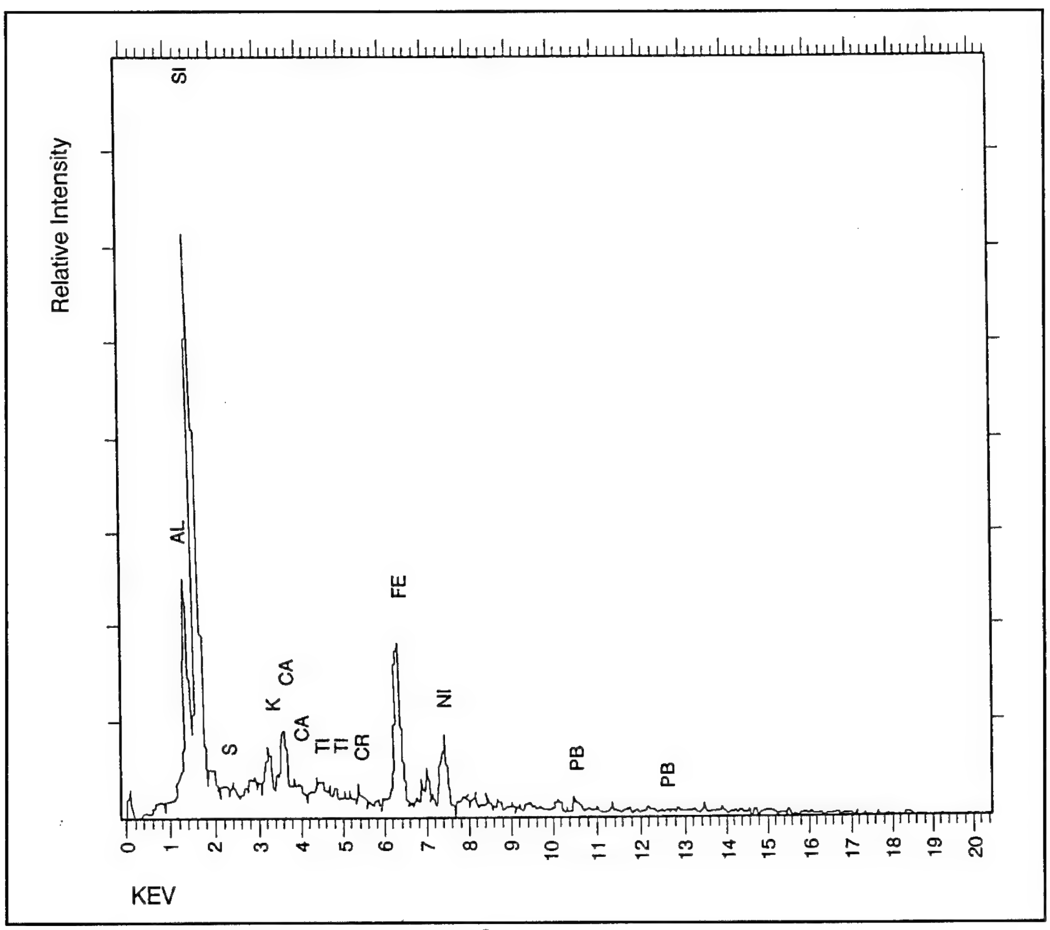

Figure 5. EDS pattern of pre-blast Blastox®.

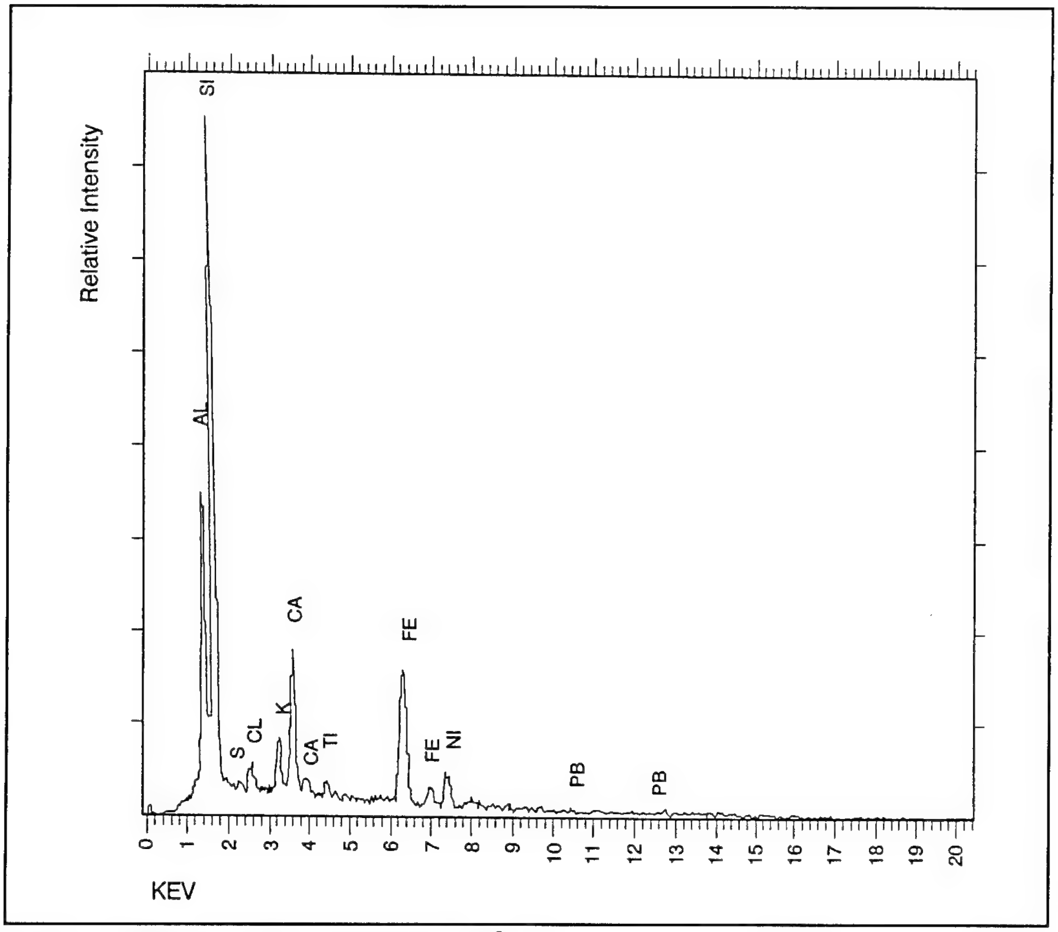

Figure 6. EDS pattern of post-blast Blastox®.

completely agree with the XRF due to the limitations of the EDS analysis, which can analyze a small part of one particle; XRF gives a composite analysis of a few grams of material, showing the difference between the elemental analysis presented in Figures 5 and 6, and Table 2.

The EDS result gave further evidence that there is no significant reaction occurring between the lead and Blastox® during the abrasive blasting stage. This EDS instrument had a lower detection limit of 3 to 5 weight percent of a single element in the sample. Therefore, there could have been some undetectable lead incorporation in the Blastox® particles. This supports the hypothesis presented before concerning the improbability of dry reactions occurring due to insufficient energy and lack of a catalyst in the system. Therefore, as expected, the process through which the lead is stabilized occurs when moisture is introduced during testing or weathering, or when water is added. Moisture might be extracted from the air to initiate some hydration reactions while in the dry state, but it was concluded that the major stabilization mechanisms involved wet chemical reactions.

Chemical Effects of Lead Solubility

The leachability of lead from a matrix is affected by many factors. Two variables account for most of the variation: (1) the chemical composition of the lead compound, and (2) the pH of the environment in which the matrix is placed. Some chemical compounds contain lead (called lead salts) that will not allow the lead to leach into ordinary solutions. Examples of such lead-containing compounds are lead phosphates, lead sulfates, organic compounds such as phthalate, maleate, and the compounds of most importance for this research, complex lead silicates. Therefore, if the lead in the paint can be extracted from the paint waste and reacted to form an insoluble lead salt, it will precipitate out of solution. This process would allow the waste to be classified as a nonhazardous waste, since the lead is stabilized.

Encapsulation in cements and/or pozzolanic ash has also been investigated as a method to treat hazardous wastes. A pozzolanic material is one comprised of finely divided silicaceons, or silicaceons and aluminous material, that reacts chemically with slaked lime at ambient temperatures in the presence of moisture to form a slow hardening cement. These similar processes will be discussed together with specific differences noted. These are methods of physically encapsulating the lead-containing paint chips within a matrix, which, on solidification, limits the amount of water that will come into contact with the waste, therefore limiting its leachability.

Cements are alkali materials with pHs in the range of 12.5 to 13.5. This is important because lead is readily soluble in this pH range (Figure 7). However, since the cement matrix limits the amount of water that comes into contact with the waste, leaching rates within the matrix are sufficiently low. This advantage is not noticed during the TCLP because the waste must be crushed to be tested. This increases the surface area for water to attack and for the waste to leach. Also, the waste is mixed throughout the test period, preventing solidification. However, the dissolution and diffusion out of the matrix limits the rate of hazardous constituent release.

Research has been performed on different cement compositions to determine if any reaction occurs between the calcium silicates and lead. Bishop (1988) showed in sequential batch tests that lead was not leached until after all the alkalinity was leached, after which the dissolution of lead paralleled the leaching of silicon. This is strong evidence to indicate that lead hydroxide is not simply physically encapsulated in the cement gel matrix, but is chemically bound when it reacts to form some type of complex silicate.

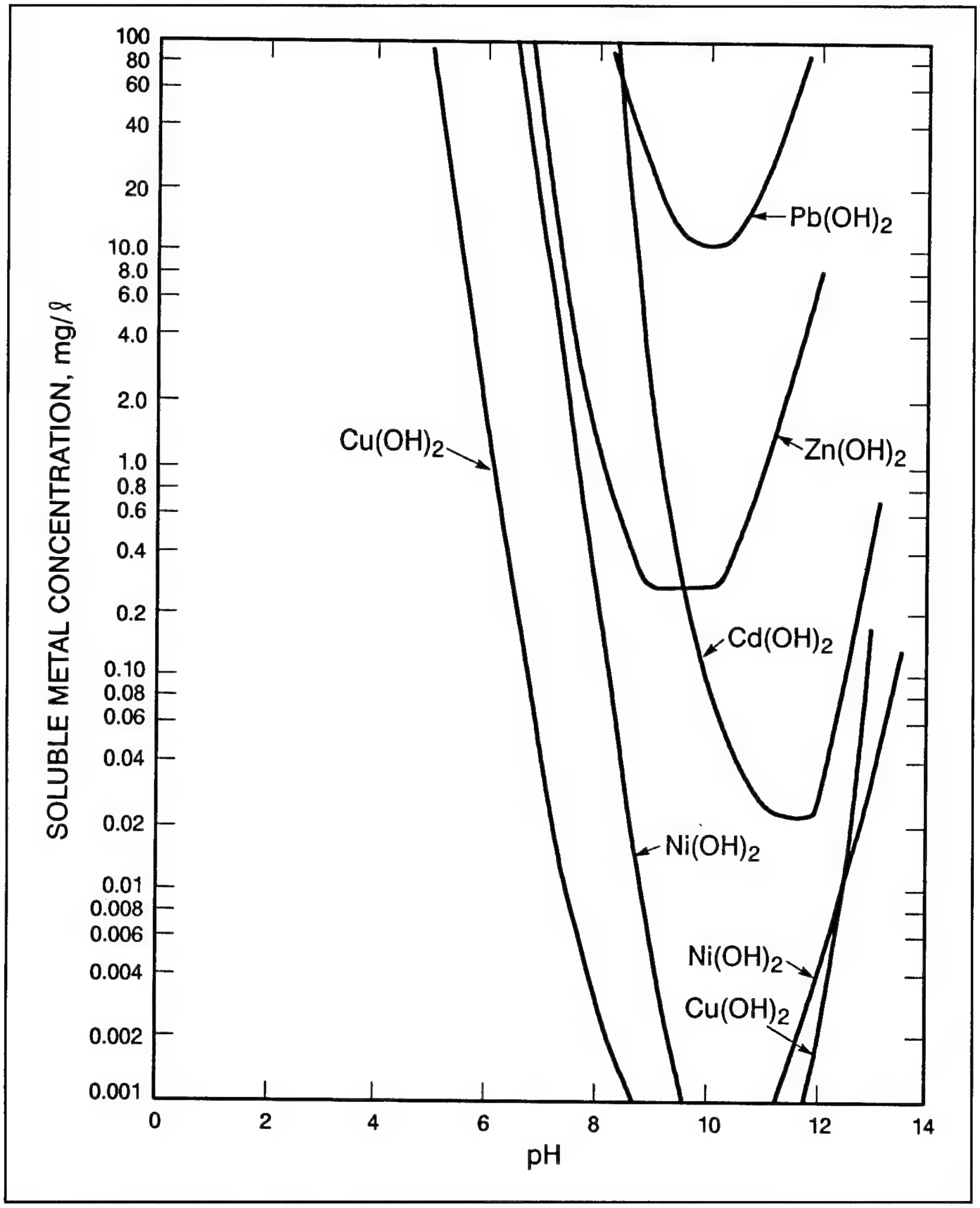

Figure 7. Theoretical solubilities of selected amphoteric metal hydroxides.

Bhatty and West (1993) postulated that lead is fixed by an addition reaction, forming a metallic calcium silicate hydrate. In actuality, it is probably not a simple silicate and almost certainly not a stoichiometric form. Some investigators believe that the lead hydroxide is simply encapsulated in the silica matrix (Connor 1990). Thus it cannot be removed unless the matrix is destroyed. This seems unlikely, since diffusion would allow dissolution of the acid-soluble hydroxide particle at a faster rate than is evident in Bishop's work. As the curing time for the pastes increases, the leaching rates of lead decreases. The lead is strongly bound in the cement product

matrix, and since the formation of silicates is also the basis for pozzolanic systems, it is likely that lead is also respeciated in that system (Akhter et al. 1990).

Earlier research has shown that these types of calcium silicates will readily react with heavy metals, including lead, by the exchange of structural Ca^{2+} by the heavy metal (Komarneni, D. Roy, and R. Roy 1982; Komarneni 1985; Komarneni et al. 1988). The results of these tests show that, in almost all cases, at least 99 percent of the lead was removed from the solution as lead silicate complex precipitates for various forms of calcium silicate. The reason for this uptake is related to their alkali cation exchange capacities (CEC) according to early Komarneni theories, or due to the exchange of Ca^{2+} for Pb^{2+} within the silicate structure as Komarneni's latest results show.

The other factor that greatly affects the leachability of lead carbonates and oxides is the pH of the solution in which it is placed. Lead is an amphoteric material, which means that the solubility is high in both strongly acidic and basic solutions, and low at intermediate pH levels. Figure 7 showed how the solubility of lead hydroxide depends on the pH of the solvent (Cullinane, Jones, and Malone 1986).

The parabolic curve in Figure 7 shows high solubility rates at pHs below 7 (a neutral to acidic solution) and above 12.5 (a highly alkaline, or basic, solution). The solubility of these lead compounds is at its minimum at a pH in the range of 9.5 to 11.5. Therefore a material can control the leachability of lead carbonates and oxides by controlling the pH of the solvent. However, controlling the pH of the solution might not limit the leachability sufficiently to allow less than 5 ppm lead to leach from a 100-g sample in 2 L of solution over 18 hours, as necessary to pass the TCLP test. This would depend on the surface area of the paint debris, the amount of lead in the solution, and the type of lead compound present. The USEPA's *Handbook for Stabilization/Solidification of Hazardous Wastes* (Cullinane, Jones, and Malone 1986) suggests that the solubility of lead can be minimized by controlling the pH. It further states that calcium hydroxide and calcium carbonate are good choices for stabilizing the pH in the desired range (9.5 to 11.0) due to their strong buffering effects,* availability, and low cost. It also states that calcium carbonate would have added benefits for stabilizing lead, considering the low solubility of lead carbonate and its compatibility with Portland cement. Lead carbonate is less soluble than lead hydroxide or lead oxide, especially at lower pHs (Conner 1990).

* A buffer is a solution that contains both a weak acid and a weak base. A buffer can therefore neutralize small quantities of either a strong base or a strong acid.

To determine the solubility of white lead as a function of pH, control samples were made with a known amount of lead and tested at different pH values by the same procedures outlined in USEPA Method 1311 (TCLP). The samples consisted of 0.086 g of white lead pigment in 100 g of silica sand to give control samples with approximately 700 ppm total lead, which is expected to exceed the levels found in most blast media debris.* The TCLP Extraction Fluid #1 was used for all the samples. However, before adding the solid samples to the solution, the pH values of all solutions were adjusted to the desired levels. After the samples were added to the solution, they were regularly checked and adjusted to maintain a constant pH. The pH level of the solution was not adjusted during the last 6 hours to allow the lead levels to stabilize. The results (Figure 8) shows the limited solubility of white lead pigment in the pH range of 8 to 11.

These results are important because they show that a pH adjustment can permit a sample containing lead to pass the TCLP. Therefore, a material, e.g., calcium carbonate, could be added to a blast medium before the abrasive blasting of lead-based paint, or as a treatment of hazardous waste after blasting, to stabilize the pH of the test solution, enabling the resulting waste to pass the TCLP test without actually stabilizing the waste. These results also show that a noticeable decrease in the leachability begins at a pH of 7.5, and a pH of at least 8.0 and less than 11.5 is critical for producing a nonhazardous waste. As previously explained, this is not to be considered an acceptable stabilization technique because the buffering effect is

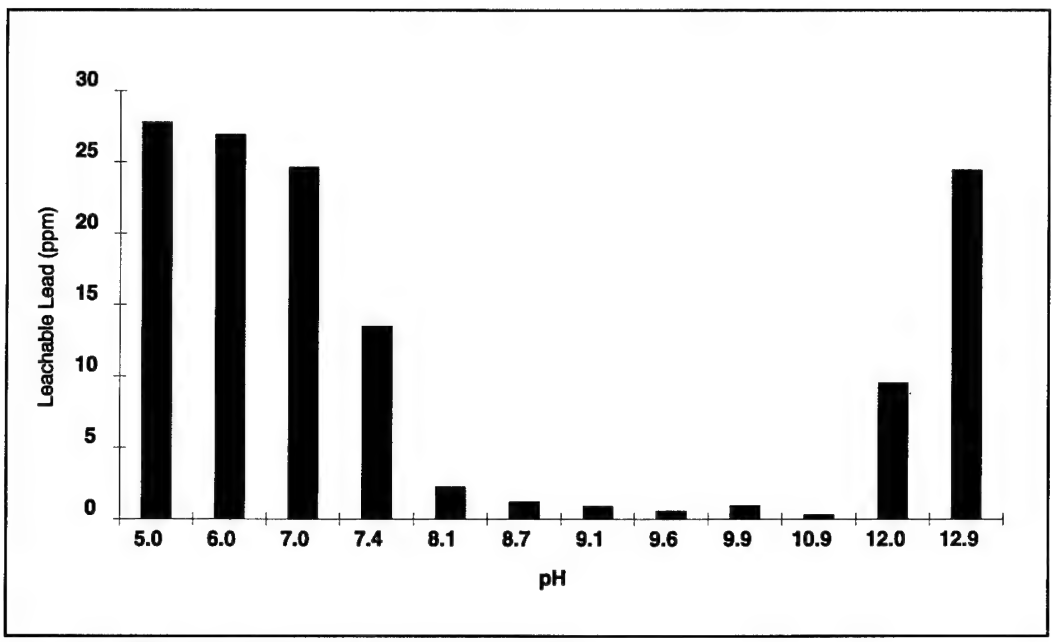

Figure 8. White lead leachability as a function of pH.

* A sample with this concentration of lead will leach a maximum concentration of 35ppm in the TCLP extraction.

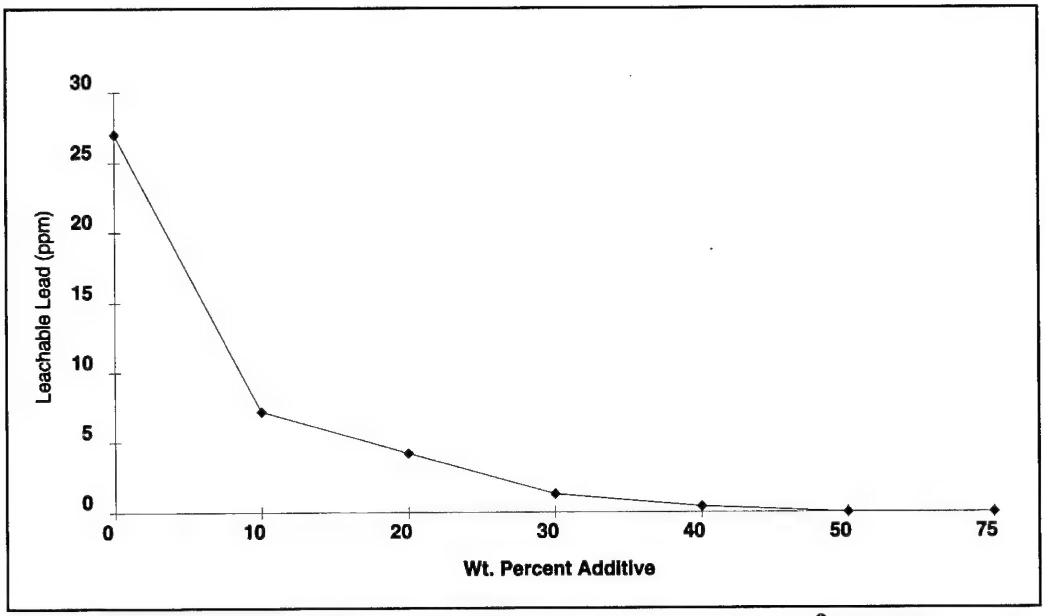

Figure 9. White lead leachability as a function of weight percent Blastox® (pH=7.0).

only temporary; once the effect wears off, the lead becomes available to leach into the environment.

The results shown in Figure 8 prompted the next set of tests, which consisted of varying the amount of Blastox® present in a sample of known amount of lead at a stabilized pH of 7.0. The samples consisted of 0.086 grams of white lead pigment, which is equivalent to 700 ppm total lead, in a 100 gram sample. The remainder of each sample is made up of 10, 20, 30, 40, 50, and 75 weight percent Blastox® in silica sand. The samples were placed in a TCLP solution that had been adjusted to a pH of 7.0 before adding the sample. The pH of the solution was then slightly adjusted—continuously (except for the last 6 hours)—to maintain a value of 7.0 for all samples. The results (Figure 9) show that, at a stabilized, neutral pH, lead leachability is inversely proportional to the amount of Blastox® present in the sample. In this particular test, a medium consists of at least 20 weight percent that resulted in lead leaching at a level less than 5 ppm under the stringent test conditions. This verifies that the chemical stabilizer's mechanism of controlling the leachability of a sample is not based strictly on buffering the pH. This decrease in the lead leachability can be explained by the formation of insoluble lead silicates. Some researchers believe that chelating is a stabilization mechanism associated with Portland cement. This is not believed to be a major stabilization mechanism associated with this material due to the small percentage of calcium silicate hydrate present, and the fact that the material is never physically mixed after the addition of the leachate. It is not necessary for the waste to cure before the lead is stabilized.

These test samples were very important because they demonstrated that Blastox® greatly affected the lead leachability, even during rigorous testing. The test conditions were designed for a "worst case" scenario. First, unbound white lead pigment powder ($PbCO_3.PB(OH)_2$) was used instead of white lead pigment bound in paint chips. Thus the lead compound had greater surface area exposed to the acid and did not have to diffuse through the organic binders in the paint. Second, acetic acid was continuously added to the test solutions until the buffering effect of Blastox® was overcome. Approximately 5 to 7 times more acetic acid was added than the standard test method requires. The hydration reactions need an alkaline environment to achieve maximum strength. Since the pH was adjusted often, the hydration reactions could not proceed as normal. The pH adjustment also limited the amount of silica in solution, as its solubility is dependent upon pH. Blastox® reduced the lead solubility during this test despite the lead pigment's higher exposure to the leaching solution and the acidic conditions of the test.

Durability

If the chemical stabilizer actually respeciates the lead carbonates and hydroxides to lead silicates, and if the lead silicates are as stable as reported in the literature, then a typical blasting waste containing the chemical additive should be able to pass the USEPA Method 1311(TCLP), back-to-back TCLP tests, and the Multiple Extraction Procedure (MEP), USEPA Method 1320. TCLP tests were performed on typical blasting waste containing the stabilizer. The two different extraction fluids were used to determine the performance in solutions of varying acidic contents. Table 3 shows the results of some of these tests.

Since the product was able to pass the TCLP test with both solutions, multiple TCLP extractions were performed back-to-back on the same set of samples. The multiple extraction tests would give information on the stability of the product in a simulated landfill over time, and after repeated additions of acid to the matrix. It would also give more information on the performance of the product after the pH buffering effect was overcome. Five back-to-back TCLP tests were performed, and the final pH of the leaching solution was recorded (Table 4 and Figure 10).

The results confirm that, even if the material is placed in a low pH environment, the lead leachability is controlled. The final two tests were performed in a solution with an initial pH of 4.9 and a final pH of 5.2 and 5.1 (i.e., there was no pH adjustment). The highest value of leachable lead in all 5 tests was 0.38 ppm, less than one-tenth the 5.0 ppm limit. These positive results prompted analysis of the waste using MEP, which is another stringent test (Figure 11).

Table 3. TCLP results of a blast media containing Blastox® and lead pigment.

Sample Number	Blastox® in Medium (Wt%)	Ca Leached (PPM)	Pb Leached (PPM)	TCLP Solution (Initial pH)	TCLP solution (Final pH)
1	15	2657	0.8	2.8	10.2
2	15	2737	0.5	2.8	8.6
3	15	877	0.5	4.8	11.2
4	25	1497	0.3	4.8	11.3
5	25	2055	0.6	2.8	10.3
6	25	2885	0.5	2.7	9.9

Table 4. Results of 5 back-to-back TCLP tests.

Test Number	TCLP Pb (ppm)	pH of Solution Prior to Additions of Waste	Final pH of Solution
1	0.105	2.83	10.7
2	0.064	4.89	9.47
3	0.127	4.89	8.26
4	0.380	4.89	5.26
5	0.163	4.89	5.11

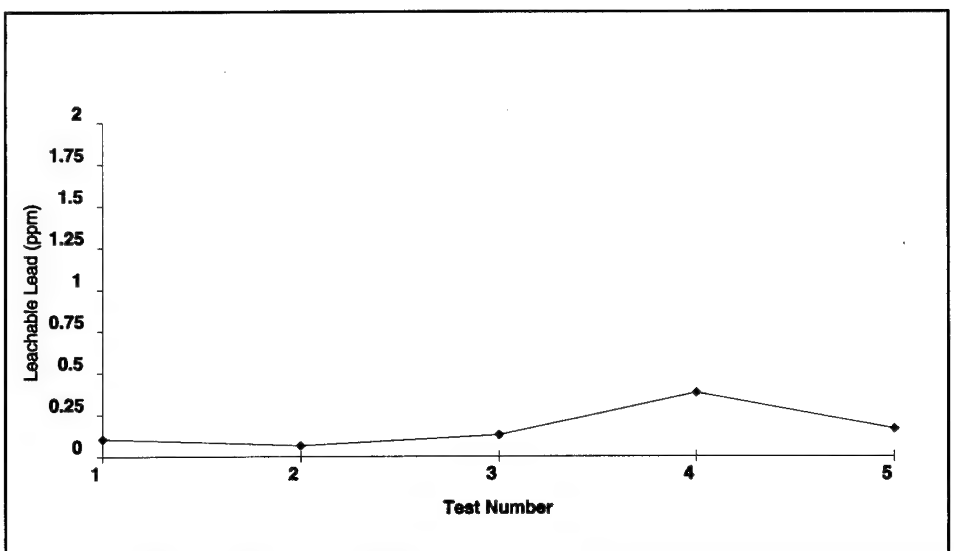

Figure 10. Back-to-back TCLP tests with additive.

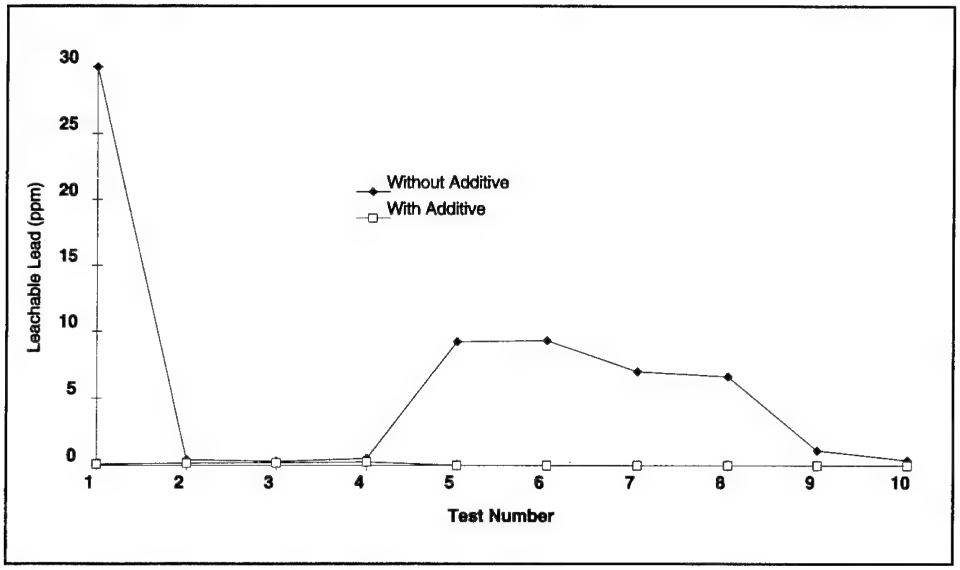

Figure 11. MEP results with and without additive

The waste with the additive passed all cycles, with a maximum lead leachability level of 0.2 ppm. On the last six cycles, the lead levels were below the detection limits of the apparatus. If a material has a potential to create a waste of questionable long-term stability, one would expect the leachable lead level to increase with the number of cycles. As explained, these results showed no lead leachability in the last six cycles.

These laboratory results, along with those given in Table 4 and Figure 10, give strong evidence that, as long as the materials (lead and calcium silicates) are able to react fully, there is no laboratory evidence of problems associated with their long-term stability. The pH buffering effects were eliminated, showing no dependence on a pH adjustment for stabilization.

Some preliminary screening tests were conducted to simulate effects of long term exposure in a landfill. The tests used do not necessarily represent a full range of landfill conditions. The waste from abrasive blasting operations was placed inside a filter placed over an Erlenmeyer flask. Then a vacuum was applied to the system such that when fluids were placed in the filter, the vacuum would draw the water through the waste and filter into the flask. By controlling the amount of vacuum, one could control the time that the fluid was in contact with the waste.

Samples with 15 and 25 weight percent Blastox® were tested in solutions varying from distilled water to a solution of distilled water and 5 percent acetic acid (a solution with a pH of approximately 2.0). The total amount of lead that leached from the waste by the various solutions was then measured.

Twenty five combinations of acidic solutions, weight percent Blastox®, and hold times of the acid being in contact with the wastes were tested. Despite the varied conditions, one sample leached 3 ppm lead, but this sample was an outlier, as all other samples leached less than 1.5 ppm lead, and the average was below 1 ppm.

Discussion of Laboratory Evaluation

The laboratory results show that the Blastox® additive is a calcium silicate-based cementitious material capable of limiting the leachability of lead carbonates, hydroxides, and oxides. Figure 9 shows that Blastox® limited the leachability of the lead, even after the pH buffering effect of the additive was overcome. Figures 10 and 11 show that the waste was stable even after being cycled repeatedly in a very acidic solution. There was no significant buffering effect after the third TCLP solution, giving strong evidence that other lead stabilization mechanisms were present, and that this additive is not merely a buffering agent. Even strongly acidic solutions passing through the waste, as acid rain would in a landfill, were not capable of extracting unacceptable lead levels.

All laboratory results show that lead-containing wastes were stabilized with the additive and that the leachability of the lead was greatly reduced; however, no analytical proof of an unleachable lead compound had been found. It was hoped that the research would show conclusive evidence of the formation of a lead silicate. This and prior (cited) research show this to be a difficult task for the following reasons:

1. Under normal conditions, there would be less than 1 weight percent lead silicates in the waste.
2. The lead silicate is in a complex, nonstoichiometric form, and is most probably not crystalline (Conner 1990).
3. There are a number of different lead silicate compounds that can be formed (i.e., lead orthosilicate, meta silicate, or tetra lead silicate) and the concentration of any compound would be very low and difficult to measure.

Komarneni et al. (1988) researched the reactions between calcium silicates and lead and found that the calcium silicate surface mainly contained lead while the core contained Ca, Si, and Pb, suggesting lead precipitation around the edges and reaction on the surface.

The additive is similar in composition to Portland cement, which is the basis of one of the stabilization techniques recommended by the USEPA and the research community. Though chemical stabilization with Portland cement is an accepted

technology, all the reactions associated with a system containing lead are not yet well understood. Most researchers believe that the lead is chemically combined via addition and cation substitution reactions with the calcium silicate. There is, however, little analytical proof that these reactions occur, except that the lead does not leach well from cement matrices. The lack of conclusive data is attributed to the three analytical difficulties outlined above.

Stabilization Mechanism

Based on the chemical composition of the additive, and knowledge gained from the literature of the chemical reactions associated with calcium silicate materials and lead, a number of stabilization mechanisms were hypothesized. Within the cement system, there are several possible reactions, which may occur in many possible sequences and affect the leachability of lead:

1. When initially placed in solution, Blastox® dissociates, creating carbonates and hydroxides in solution, which raise the pH of the solution to a range of 10.0 to 11.3. The effects of this are: (a) a pH above 10 promotes the hydration reactions of this product, and (b) white lead is an amphoteric material, meaning it is soluble at a low and a high pH but exhibits minimum solubility within the range of 8.0 to 11.0 (Figure 8). This reaction aids the kinetics of the stabilizing reactions by limiting the lead dissolution to assure that other reactions can occur quickly enough to stabilize all the free lead ions.
2. Due to the cementitious nature of the calcium silicate hydrate (CSH), the lead would be immobilized upon wetting of the waste. In a landfill, these wet reactions tend to create a solid mass (hydrate), which limits the amount of water that could percolate. The Blastox® containing waste does solidify or set in a similar manner to Portland cement. Similar to cement, the strength of these encapsulation reactions depends on the waste-to-cementitious material ratio, mixing, and set time.

Figures 9, 10, and 11 show that Blastox® is capable of controlling lead leachability even after the pH buffering effect has been eliminated. Figures 10 and 11 and the data in Table 4 show that the waste is stabilized in a cycled acidic solution. Also, due to the disproportionate amount of solution in the TCLP test and the fact that waste is constantly mixed during the test, the encapsulation reactions are reduced to a local level. In the TCLP test, the waste is not a solid mass, as it would be in a landfill. Instead, the hydration reactions occur on a local level, encapsulating some lead paint particles; however, it is obvious that all of the particles cannot be physically

encapsulated while the mixture is being constantly tumbled during TCLP. Therefore, there must be other stabilization mechanisms at work within this system.

Two other possible mechanisms may be responsible for the stabilization of lead and the long-term durability of the waste. One mechanism involves an intermediate step—the formation of lead carbonates. When cementitious materials are placed in solution, carbonates are dissolved. Free lead ions are also in solution due to the dissociation of lead oxide or lead hydroxide. The free lead can react with the carbonates in solution, and precipitate as lead carbonates, which have limited solubility. The other mechanisms believed to be present within the system are the addition and cation substitution reactions between lead and calcium silicates, which create an insoluble complex lead silicate.

It is also hypothesized that, over time, the lead carbonate would be respeciated to a lead silicate. As the environment surrounding the waste fluctuates, the lead carbonates dissociate, causing the lead to redissolve, then react with the silicates. The end result of all these reactions is believed to be a complex lead silicate. While no tangible evidence of these reactions were found in this study, these hypotheses are consistent with data from the published literature. As mentioned, the lead is not stabilized within this system simply by the pH buffering or the encapsulation caused by the hydration reactions. There must be other mechanisms involved, and these hypotheses were developed based on the composition of the additive and the reactions associated with calcium silicates and lead. The results and hypothesis support the published and laboratory data, and no contradicting evidence was found.

One possible way to verify that lead is converted to lead silicate would be to perform an extraction and analysis of the pore solution from a calcium silicate-based cement, Blastox®, and LBP waste. Pore solutions recovered after set are typically found to be concentrated solutions of alkali hydroxides with modest contents of other compounds. The overall pH of the pore solution is extremely basic, with a pH of 10 to 12. This is the chemical environment that any foreign species introduced from the hazardous waste, would encounter during stabilization. Understanding the behavior of foreign species such as lead in this specific chemical environment has provided insight into the chemical processes that occur during stabilization of hazardous metals. The expression of pore solutions may be conducted on engineered abrasives that are allowed to hydrate and form solid compacts. This test would provide more evidence of the basic mechanism of lead stabilization in a silicate matrix (Boy et al. 1994, 1996).

4 Field Test of Chemical Stabilizers

Field Test Approach

USACERL conducted or participated in four field demonstration of Blastox® at three installations:

1.	July 1993	Building T4561, Fort Meade, MD
	July - August 1994	Water Storage #8, Fort Meade, MD
2.	January 1994	Sewage Treatment Plan, Fort Carson, CO
3.	January 1994	Family Housing Unit, Fort Hood, TX

Coal slag abrasive was used in each case. The abrasive was selected because it is available in a particle size range that matched that of the Blastox® additive. Blastox® is also available mixed with other abrasives, such as copper slag and silica sand. Blastox® was mixed into the coal slag abrasive at a rate of 25 percent by weight for the three wood-sided buildings, and at a 20 percent rate for the steel water storage tank.

At each demonstration site, samples of the solid waste were collected for TCLP analysis in accordance with the random sampling procedures outlined in the *USEPA Test Procedures Manual* SW-846 (November 1986).

Field Test Results: Building T4561 at Fort Meade, MD

Figure 12 shows the lead-painted building (T4561) at Fort Meade before the abatement procedure.* Before removing the LBP, XRF analysis was done on each side of the building (Figure 13). Table 5 lists a lead content of 0.0 to 10+ mg/cm^2, indicating significant amounts of lead present in the paint on each side of the building. A 50 sq ft test sample was then abrasively blasted (without Blastox®) to determine the amount of leachable lead in the waste sample without the additive. The data in Table 5 list a range of 7.3 to 14 ppm of leached lead in samples with no Blastox®.

* The contractor who sand-blasted the building at Fort Meade was: Steven Eva, 34208 Aurora Rd., Solon, OH 94139, tel: 800/787-4747.

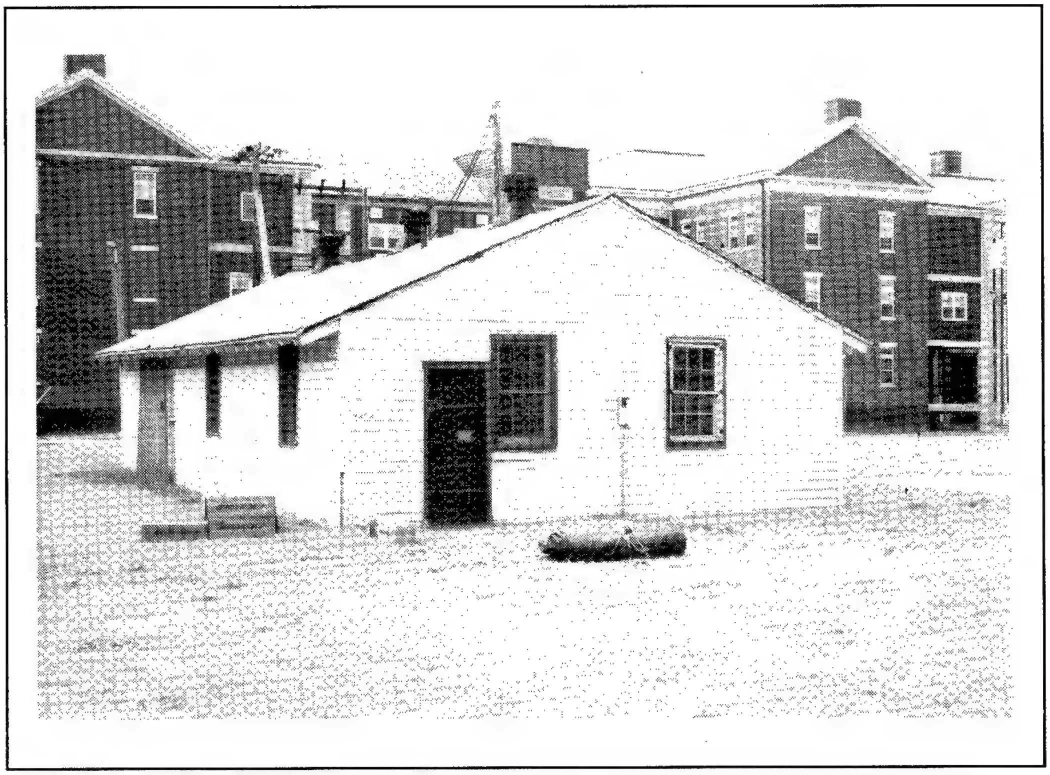

Figure 12. North and east walls of Building T4561 before demonstration at Fort Meade.

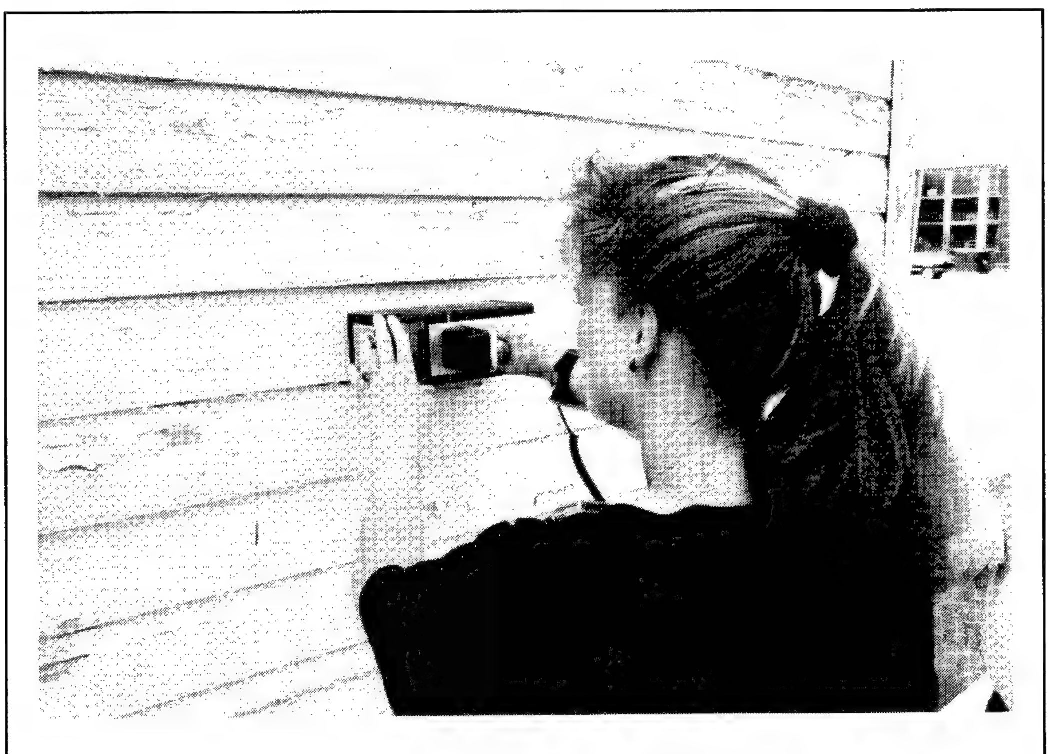

Figure 13. XRF reading being taken before sand blasting at Fort Meade.

Table 5. TCLP and XRF results of Fort Meade samples.

Side of Building	Blastox® in Sample[1] (Wt.%)	XRF Before Blasting, Lead (mg/cm^2 ±0.5)[2]	XRF After Blasting Lead[2] (mg/cm^2±0.5)	USACERL TCLP Results ppm Lead[3]	Ft. Meade TCLP Results Leached ppm Lead[4]
North	0.0			12.00	13.50
East	0.0			14.00	13.60
West	0.0			7.30	9.44
North	30.0	0.0-9.1	0.0-0.3	4.70	0.10
South	30.0	0.0-1.0	0.0-0.4	0.58	0.10
East	30.0	2.6-10+	0.0-0.8	1.70	0.10
West	30.0	0.7-7.8	0.0-0.6	0.58	0.10

Notes:
1. Abrasive blast media consisted of coal slag or a blend of 70 wt% coal slag and 30 wt% Blastox ®
2. Each XRF result reported is an average of three readings. The lower value in each range represents the lead loading on the lower portion of the wall, which is more weathered and has retained less of the old lead-based paint. The higher values were measured on the upper portion of the wall, protected by the roof overhang, where more of the original paint remains. The XRF analyzer, a Princeton Gamma-Tech Model XK3, reports all readings of 10.0 mg/cm2 or greater as 10.0. Therefore, a reported value of 10+ denotes a lead level of 10 mg/cm2 or greater.
3. A waste that leaches more than 5 ppm lead per 100 grams is classified as hazardous, and must be handled accordingly.
4. Detection Limit = 0.10 ppm for the Fort Meade equipment

The building containment, as shown in Figures 14 and 15, protected the environment from lead contamination. Blastox® was then blended on site (30 weight percent)* with coal slag prior to abrasive blasting the rest of the LBP remaining on the building.

The XRF data in Table 5 show less than 0.8 (± 0.5) mg/cm^2 of lead remaining on the building exterior. This translates to a lead hazard-free building exterior as defined by the Maryland USEPA (Figure 16). The TCLP results from the waste product consisting of spent abrasive, LBP, and Blastox® (Table 5) show that, in all cases, lead leached below the USEPA limit of 5 ppm. The TCLP data from both USACERL and Fort Meade are 0.10 to 4.7 ppm leachable lead—less than regulatory threshold of 5 ppm leachable lead.

The actual cost of abatement was $2.50 per sq ft, much less than that of other methods such as power tool cleaning or chemical stripping. This cost would also decrease as additional numbers of FHUs were abated on a particular site. Table 6 lists detailed costs associated with this job. All air-monitoring levels were below the USEPA's cutoff values (Table 7). The workers wore personal air monitors on their suits, near their masks. Table 8 gives the lead levels from these monitors, which are well below the Occupational Safety and Health Administration (OSHA) cutoff values of 1200 $\mu g/m^3$ for the type of mask used.

These samples were taken with a filter 37 mm in diameter at a pump rate of 4 L/min. The action level is 30 $\mu g/m^3$ or 0.03 mg/m^3 (cf. 29 CFR 1910.1025) as an average of all filters, and the average of the above values is 20.375 $\mu g/m^3$. All values were below the action level, except two. The containment was specified at 85 percent.

* Note that this field demonstration was conducted before completion of the laboratory tests of Blastox®. This conservative 30 weight percent Blastox® was used prior to the determination that 25 percent is sufficient for removal of LBP from wood.

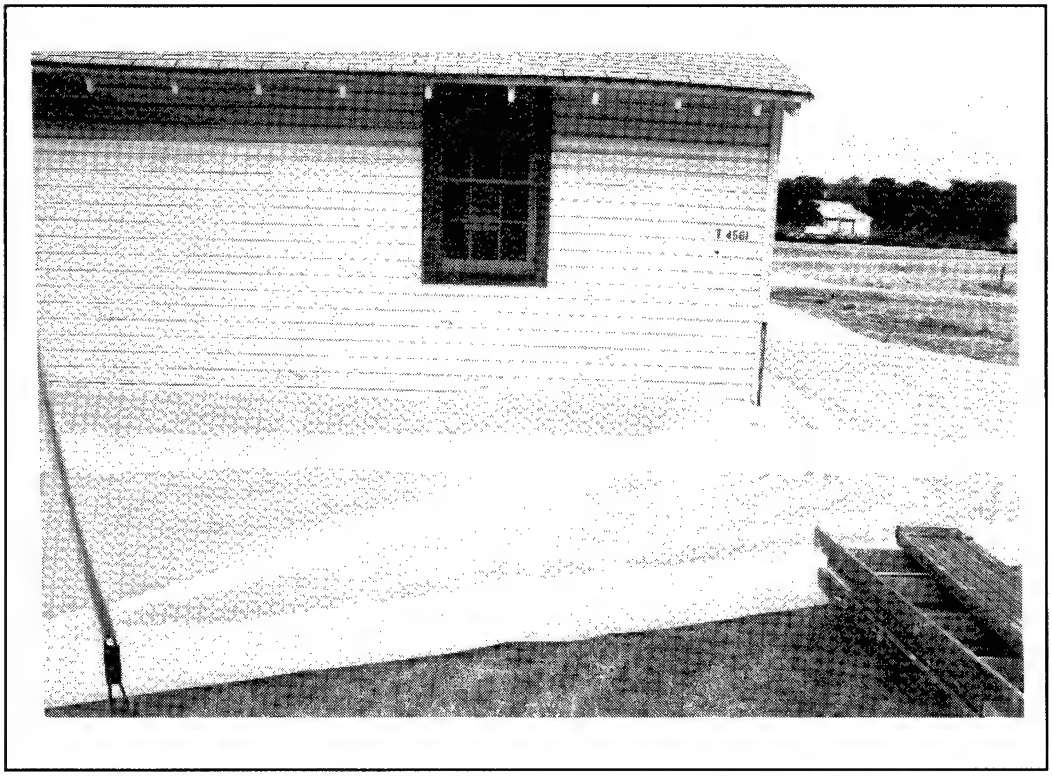

Figure 14. Polyethylene tarps create a continuous ground cover to protect soil at Fort Meade.

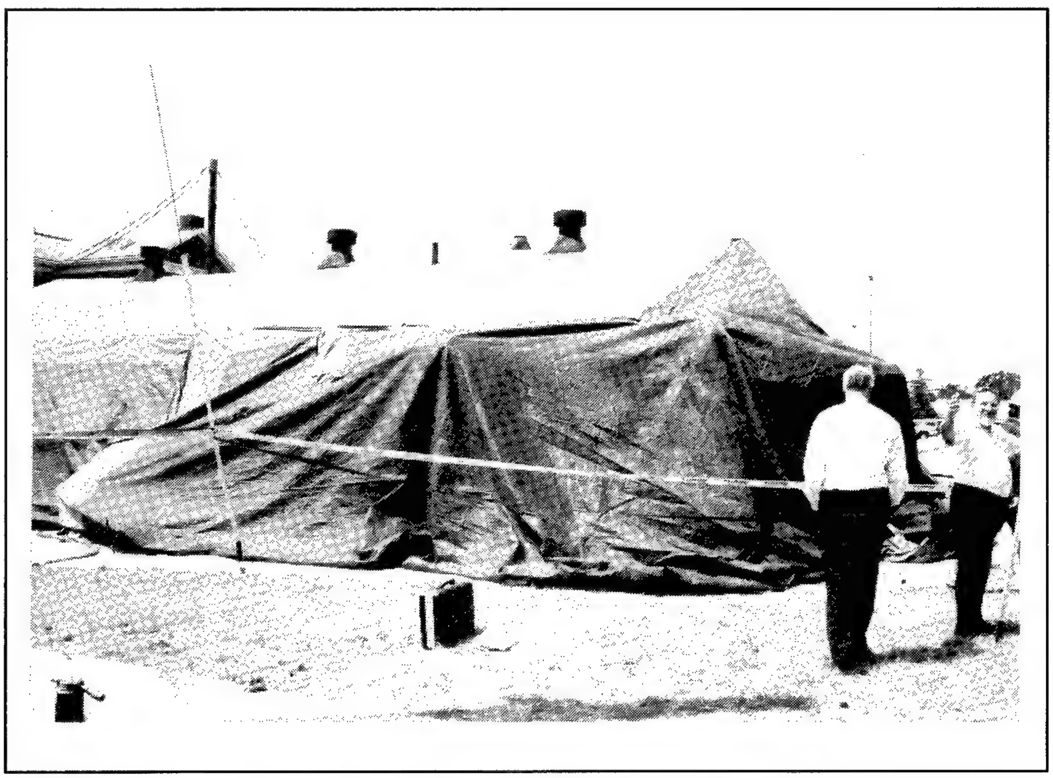

Figure 15. Completed enclosure for waste containment at Fort Meade.

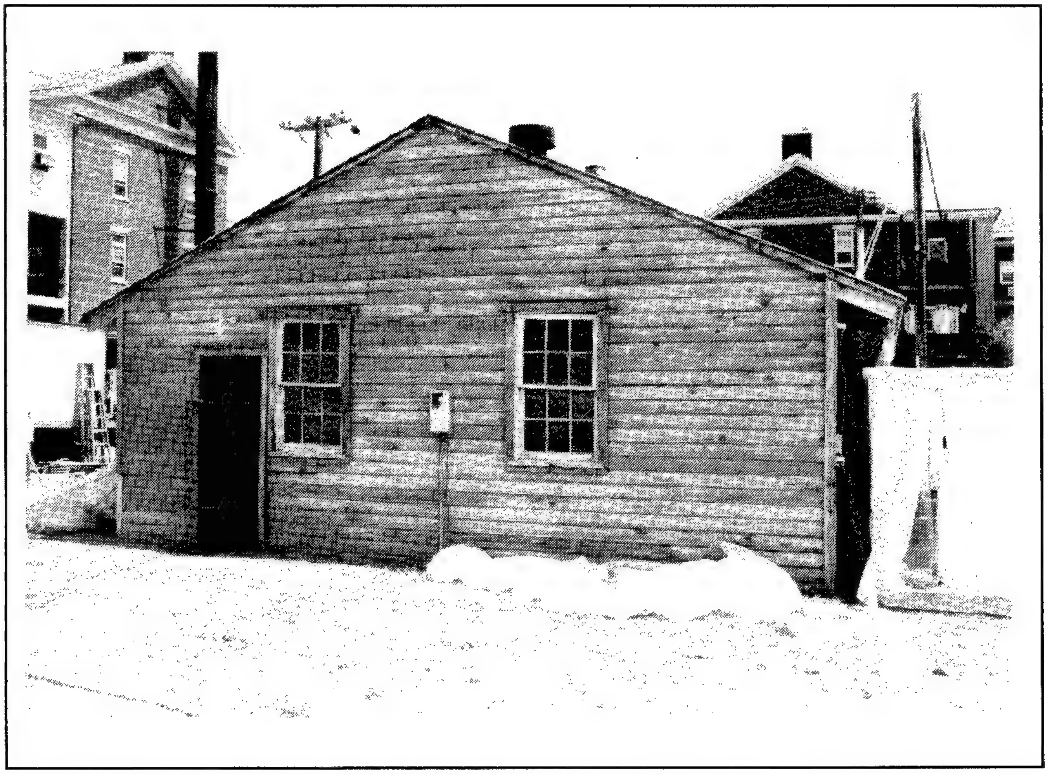

Figure 16. The end result: a lead-hazard free building at Fort Meade.

Table 6. Direct cost to contractor at Fort Meade.

Description	Cost ($)
Labor, 2 day, 4 workers (average wage & benefits)	1,600
Abrasive	250
Blastox®	300
Fuel (equipment only)	50
Disposal ($60 per ton plus handling)	250
Testing	225
Containment supplies	225
Safety equipment	100
Total direct costs	$3,000
Total area of paint removed (sq ft)	1,200
Total cost per sq ft	$ 2.50

Table 7. Personal air monitors results at Fort Meade.

Personal Air Monitor	Worker #	Day #	Lead Levels (μg/m³)
#3	1	1	38.0
#4	2	1	65.0
#5	1	2	19.0
#6	2	2	316.0

Notes:

1. The maximum airborne lead levels are 2500 μg/m³ (1.25 mg/m³)as established by 29 CFR 1926.62 (b) (2) (c), table 1 for the types of masks used, which were full face, negative pressure cartridge respirators.
2. Samples were taken with an air flow of 2.5 L/min.
3. There was no reported increase in the blood lead levels of the workers for this project

Table 8. Area air monitoring results from Fort Meade.

Date	Sample #	Site of Filter	Lead ($\mu g/m^3$)
12 Jul 93 [1]	22090	South of containment	16.5
	22091	South of containment	11.8
	22092	South of containment	34.8
13 Jul 93 [2]	22093	Northeast of containment	0.217
	22094	East of containment	17.5
	22095	Southeast of containment	13.5
	22096	Southwest of containment	17.0
	22099	West	0.13
	22100	Southwest	0.13
	22101	Southeast	9.42
	22102	Interior of building	3.75
15 Jul 93 [3]	22103	Northwest of building	6.79
	22104	West	8.70
	22105	Southwest	11.40
	22106	Interior of building	154.00

Notes:
1. 12 Jul 93: Wind was approximately 5–10 mph from the north-northwest
2. 13 Jul 93: Very slight wind from the north
3. 15 Jul 93: Very slight wind from the north

Field Test Results: Fort Carson, CO

Figure 17 shows the lead-painted building (sewage treatment plant) at Fort Carson before the abatement procedure.* The Fort Carson results closely resemble Fort Meade's, except for the air monitoring. In this demonstration, a 100 percent containment system was used instead of the 85 percent system used at Fort Meade (Figure 18), so that the amount of lead detected by area monitors outside containment was much less at Fort Carson (Table 9). The more stringent containment was used at the request of the installation. The TCLP results were all below 3.19 ppm lead (Tables 10 and 11). (Figure 19 shows the Fort Carson sewage treatment plant following abatement.) The cost was slightly higher than the Fort Meade, from $2.50 to $2.74 per sq ft (Table 12) due to the more stringent containment.

* The contractor employed to sand-blast the structures at Forts Carson and Hood was: James Lyskawa, of Professional Power Stripping, Inc., 81 Pinehurst Court, East Amherst, NY 14051, tel: 716/689-0451.

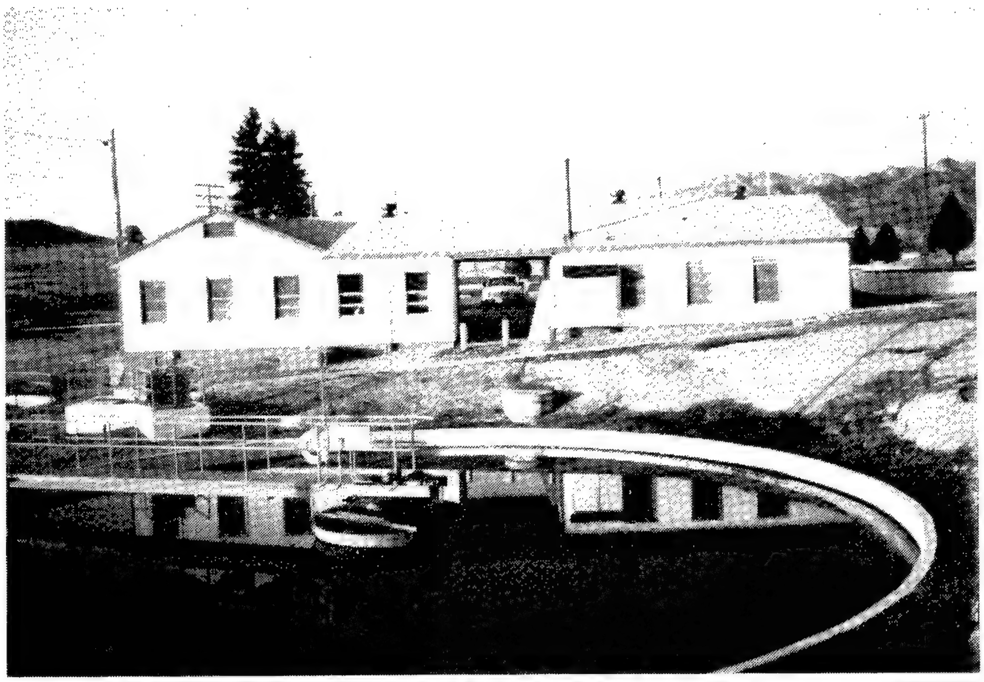

Figure 17. East side of Sewage Treatment Building at Fort Carson.

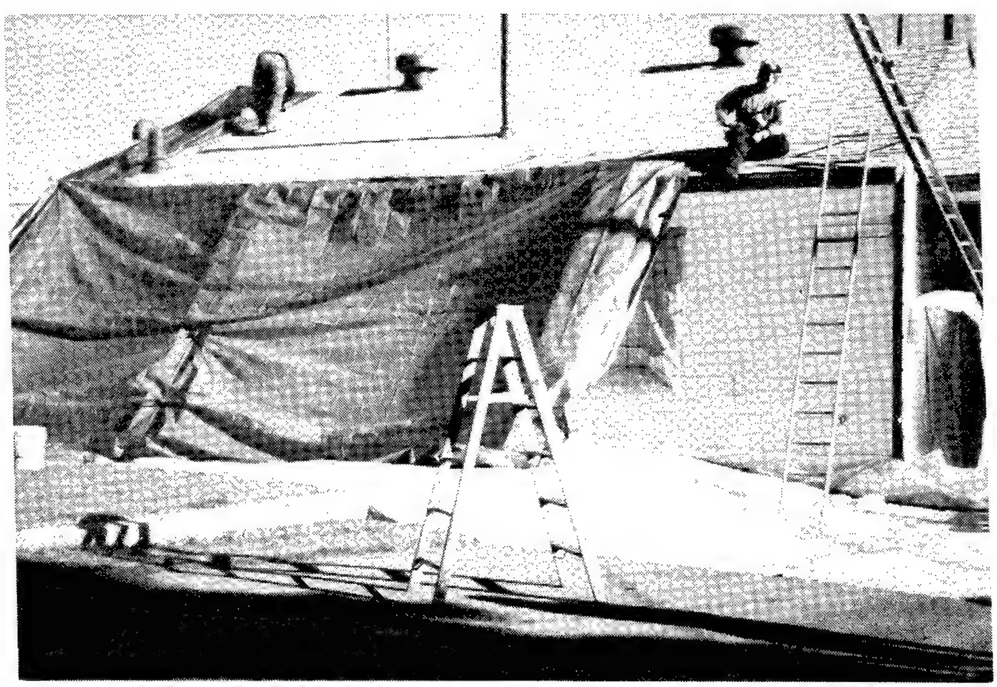

Figure 18. Containment of the Fort Carson site.

Table 9. Air monitoring results from Fort Carson.

Date	Sample #	Sample Location	Air Collected (L)	Lead ($\mu g/m^3$)
13 Jan 94	S3	Southwest corner, exterior	720	-
	S5	Southeast corner, exterior	720	-
	M-93-38	Northeast corner, exterior	720	< 1.4
	M-93-49	Exterior, Maint. Shop, south wall	720	< 1.4
	M-93-50	Northwest corner, exterior	720	< 1.4
	M-93-51	Exterior, Maint. Shop, east wall	720	< 1.4
	M-93-52	Exterior, Maint. Shop	720	< 1.4
	M-93-53	Exterior, Maint. Shop	720	< 1.4
	M-93-54	Quality Control Blank	-	< 0.001
14 Jan 94	DEC-0114-1	Operator 2	360	1583
	DEC-0114-2	Operator 3	360	1694
	DEC-0114-3	Operator 1	660	3667
	DEC-0114-4	Northwest corner, outside containment, down wind	600	< 1.7
	DEC-0114-5	Inside building, mechanical room, west wall	600	< 1.7
	DEC-0114-6	North, middle outside containment, down wind	600	1.7
	DEC-0114-7	Southeast corner, outside containment, up wind	600	1.7
	DEC-0114-8	Northeast corner, outside containment, down wind	600	< 1.7
	DEC-0114-9	Quality control Blank	-	<0.001
15 Jan 94	DEC-1015-1	Northwest corner, 10 feet from containment, outside	1070	0.93
	DEC-1015-2	North side containment, outside, 10 feet	1080	0.93
	DEC-1015-3	Northeast corner, 10 feet from containment, outside	1016.5	2.0
	DEC-1015-4	Inside Maint. Shop, 6 feet from west wall, 5 feet 5 inches up	930	2.2
	DEC-1015-5	South side, 8 feet up wind	828	< 1.2
	DEC-1015-6	Operator 1	945	1249
	DEC-1015-7	Operator 2	731.5	12
	DEC-1015-8	Quality Control Blank	-	<0.001

Date	Sample #	Sample Location	Air Collected (L)	Lead (µg/m³)
17 Jan 94	DEC-0117-1	Operator 1	668	33
	DEC-0117-2	Operator 3	590	2203
	DEC-0117-3	Operator 2	390	1487
	DEC-0117-4	Down wind, 50 feet from containment, northwest corner of building	840	1.2
	DEC-0117-5	Up wind, south side of containment, 10 feet	830	< 1.2
	DEC-0117-6	Inside south building by west window	766	16
	DEC-0117-8	Down wind 12 feet from containment by breeze way, west side	840	1.2
	DEC-0117-9	Quality control blank	-	<0.001
18 Jan 94	DEC-0118-1	Operator 1	520	52
	DEC-0118-2	Operator 3	236	212
	DEC-0118-3	Operator 2	334	461
	DEC-0118-4	Inside north Maint. Shop, east side window	848	2.4
	DEC-0118-5	South end of building, 20 feet up wind	836	< 1.2
	DEC-0118-6	North side of building, 10 feet down wind	834	< 1.2
	DEC-0118-7	North end of building, 25 feet down wind	836	< 1.2
	DEC-0118-8	Quality control blank	-	< 0.001
19 Jan 94	DEC-0119-1	Operator 1	586	5267
	DEC-0119-3	South end of building, north wall inside	314.5	3.2
	DEC-0119-4	Operator 2	710	3014
	DEC-0119-5	10 feet down wind of containment	787.5	3.8
	DEC-0119-6	5 feet down wind of containment	702	1.4
	DEC-0119-7	30 feet up wind, outside of containment	700	5.7
	DEC-0119-8	Quality control blank	-	< 0.001

Date	Sample #	Sample Location	Air Collected (L)	Lead (μg/m³)
22 Jan 94	DEC-0122-1	Operator 1	894	3629
	DEC-0122-2	Operator 4	506.8	2691
	DEC-0122-3	Up wind, outside containment, 20 feet	710.5	< 1.4
	DEC-0122-4	Down wind, outside containment, 10 feet	1212.5	0.82
	DEC-0122-5	Down wind, outside containment, 20 feet	1089	0.92
	DEC-0122-6	Inside building, east wall by window, south building	783.75	13
	DEC-0122-7	Operator 3	434	161
	DEC-0122-8	Quality control blank	-	< 0.001

Notes:
1. The samples were taken with a 37 mm cassette and collected at an air flow of 4 L per minute.
2. The action level is 30 μg/m³ as established by 29 CFR 1910.1025.
3. The containment specified was 100%.

Table 10. TCLP and XRF results of Fort Carson: North Unit.

Side of Building	Blastox® in Sample (Wt%)	XRF Before Blasting (mg/cm²)	XRF After Blasting (mg/cm²)	USACERL TCLP Results (ppm Lead)	Fort Carson TCLP Results (ppm Lead)
North	25.0	15.7	0.0	0.055	< 0.05
South	25.0	16.5	0.1	0.03	< 0.05
East	25.0	19.1	0.0	0.052	< 0.05
West	25.0	13.0	0.0	0.048	< 0.05
West	0.0[1]			45.4	

Note: 1. This was a 50-sq ft test patch performed without the additive as a background check for the building.

Table 11. TCLP and XRF results of Fort Carson: South Unit.

Side of Building	Blastox® in Sample (Wt%)	XRF Before Blasting (mg/cm²)	XRF After Blasting (mg/cm²)	USACERL TCLP Results (ppm Lead)	Fort Carson TCLP Results (ppm Lead)
North	25.0	19.1	0.1	3.19	< 0.05
South	25.0	14.1	0.0	0.201	< 0.05
East	25.0	19.9	0.0	< 0.03	< 0.05
West	25.0	37.1	0.1	0.062	< 0.05

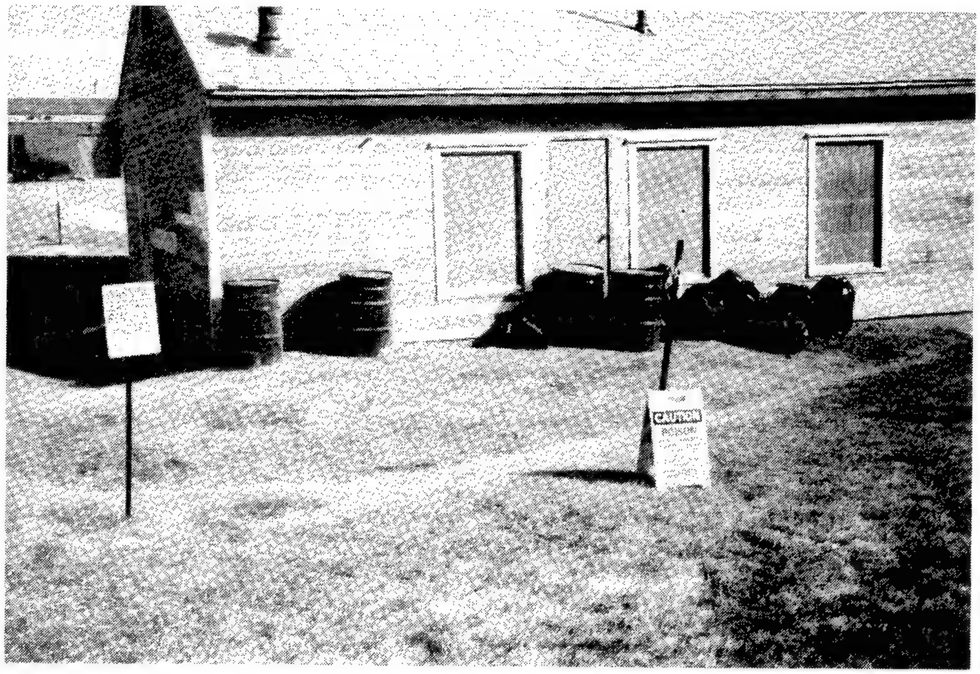

Figure 19. Sewage Treatment Plant at Fort Carson following abatement, showing nonhazardous waste placed in proper containers.

Table 12. Direct cost to contractor, Fort Carson.

Description	Cost ($)
Labor, 4 days, 14 work days	5,862
Abrasive/Blastox®	350
Fuel	115
55 gal drums (for disposal)	345
Tarps/plastic (used and disposed of)	632
Production supplies	190
Safety supplies	991
Total direct costs	$8,485
Total area of paint removed (sq ft)	3,100
Total cost/sq ft	$ 2.74

Field Testing Results: Fort Hood, TX

Figure 20 shows the Fort Hood FHU before abatement with the ground and window covers in place. The field test results are very similar to those of Fort Carson because they were performed with the same specifications, including the 100 percent containment (Figure 21). As a result, the air-monitoring results were very low (Table 13) and the TCLP results were all less than 1 ppm (Tables 14 and 15). The cost for this abatement was comparable to that of Fort Carson, from $2.74 to $2.77 per sq ft (Table 16).

Wipe samples were taken before abatement began, after the paint was removed, and after cleaning each area with one of four cleaners; Pinesol®, Mr. Clean®, Ledizolv™, and trisodiumphosphate solution (TSP).* Table 17 summarizes the wipe sample results.

There was lead dust present before abatement; however, the amount significantly increased during the removal process. With simple cleaning after abatement, the amount of lead present was near the amount present before abatement, and when Mr. Clean™ was used, the lead levels were actually lower than present before abatement. Figure 22 shows the exterior wood surface after abatement.

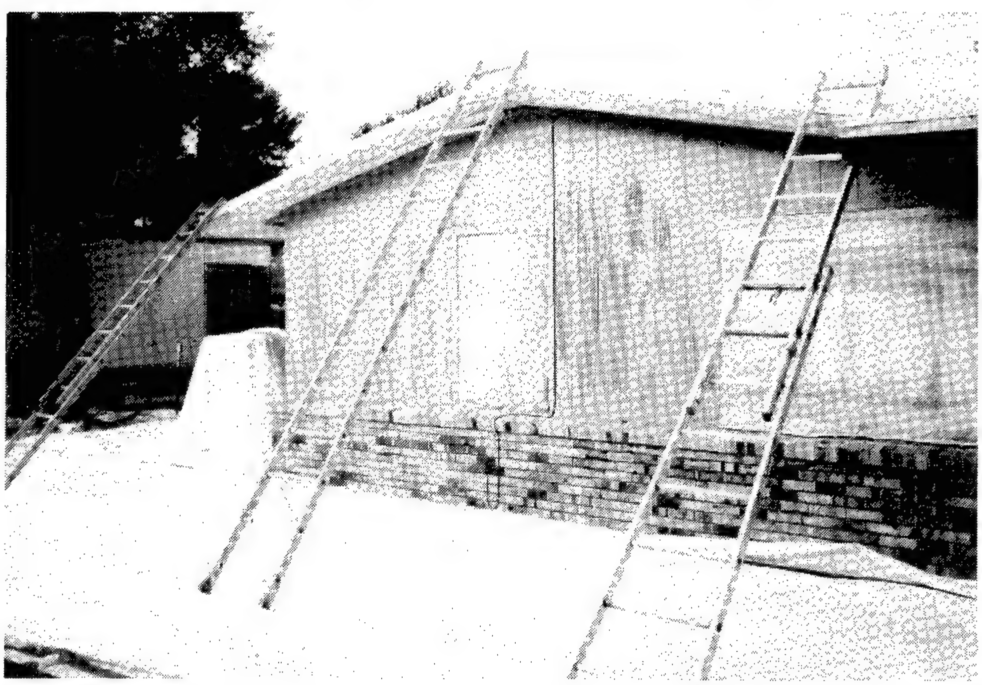

Figure 20. Fort Hood site before abatement, with ground and window covers in place.

* Pinesol is a trademark of the Clorox Co., 1228-T Broadway, Oakland, CA; Mr. Clean is a trademark of the Procter and Gamble Co., One Procter & Gamble Plaza, Cincinnati, OH; Ledizolv is a trademark of Hin-Cor Industries, Inc., 136 Sea Island Parkway, Suite 10502, Beuford, SC.

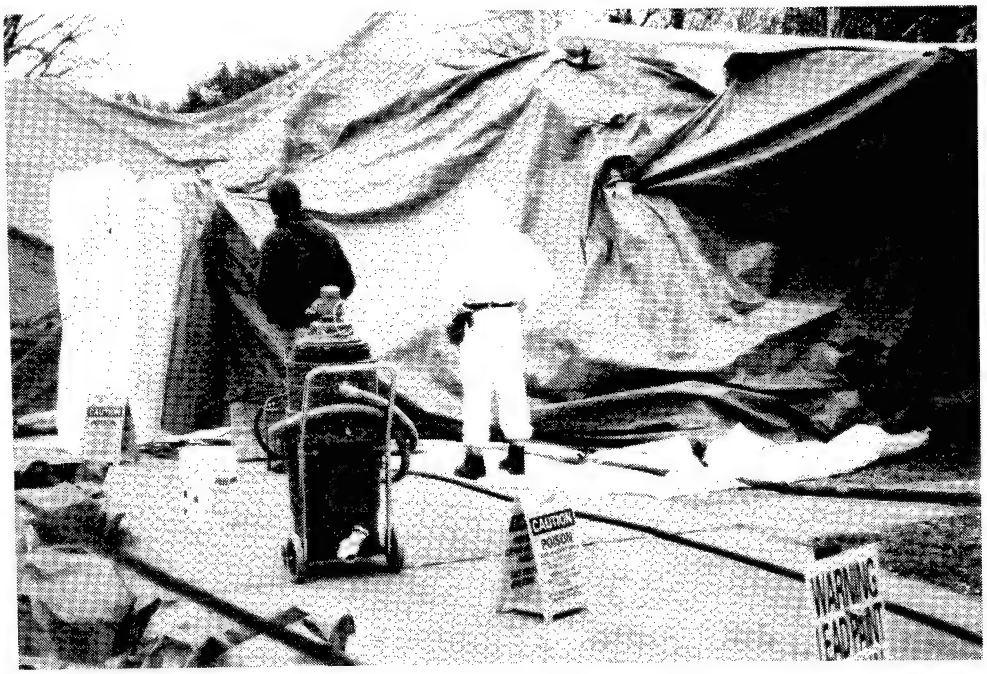

Figure 21. Containment erected and lead paint abatement in progress at Fort Hood.

Table 13. Results of area air monitoring outside containment for Fort Hood.

Date	Sample #	Sample Location	Air Collected (L)	Lead ($\mu g/m^3$)
31 Jan 94[1]	FH-001	Exterior driveway	272	< 6.0
	FH-002	Exterior patio	252	< 6.0
	FH-003	Interior kitchen	252	< 6.0
	FH-004	Interior bedroom	244	< 7.0
1 Feb 94	FH-006	Containment entrance	756	< 2.0
	FH-007	Southeast side downwind	756	< 2.0
	FH-008	Northwest driveway	316	< 5.0
	FH-009	Southeast side downwind	320	< 5.0
	FH-P101	Abatement process, inside containment	162.5	16000
	FH-P102	Sanding process, inside containment	377.5	1360
	FH-P103	Breakdown process, inside containment	162.5	16000
2 Feb 94	FH-010	Exterior north	548	< 3.0
	FH-011	Exterior downwind	552	< 3.0
	FH-012	Exterior north	452	< 4.0
	FH-013	Exterior downwind	456	< 4.0
	FH-P104	Abatement process, inside containment	125	22500
	FH-P105	Sanding process, out/inside containment	545	729
	FH-P106	Breakdown process, inside containment	215	647
3 Feb 94	FH-014	Exterior north	872	< 2.0
	FH-015	Exterior northwest	868	< 2.0
	FH-016	Exterior north	320	< 10.0
	FH-017	Interior kitchen	240	< 7.0
	FH-P107	Abatement process, inside containment	212.5	37600
	FH-P108	Sanding process, inside containment	305	10900
	FH-P109	Breakdown process, inside containment	182.5	2950

Notes:
1. All air samples collected on 31 Jan 94 represent background levels before lead abatement began 1 Feb 94.
2. Lead levels outside the containment area did not exceed 30 $\mu g/m^3$ as established by 29 CFR 1910.1025.
3. These levels are lower than experienced at Fort Meade due to the use of 100% containment at this installation, as opposed to 85% at Fort Meade.

Table 14. TCLP and XRF results of Fort Hood: Unit 1.

Side of Building	Blastox® in Sample (Wt%)	XRF Before Blasting (mg/cm^2)	XRF After Blasting (mg/cm^2)	Leached Lead: USACERL Samples (ppm)	Leached Lead: Fort Hood Samples (ppm)
North	25.0	6.5	0.3	< 0.03	0.7
South	25.0	4.1	0.0	0.136	1.5
East	25.0	11.6	0.1	0.136	< 0.5
West	25.0	11.2	0.0	0.201	< 0.5

Table 15. TCLP and XRF results of Fort Hood: Unit 2.

Side of Building	Blastox® in Sample (Wt%)	XRF Before Blasting (mg/cm^2)	XRF After Blasting (mg/cm^2)	Leached Lead: USACERL Samples (ppm)	Leached Lead: Fort Hood Samples (ppm)
North	25.0	6.5	0.0	0.20	0.7
South	25.0	14.4	0.1	0.20	1.5
East	25.0	5.1	0.1	0.20	< 0.5
West	0.0(1)	7.9	0.3	55.1	55.0

Note: 1. This was a test sample from which the paint was removed from 50 sq ft with abrasive containing no Blastox®.

Table 16. Direct cost to contractor, Fort Hood.

Description	Cost ($)
Labor, 2 days, 8 work days	2,310
Abrasive/Blastox®	102
Fuel	50
55-gal. drums (for disposal)	138
Tarps/plastic (used and disposed of)	345
Production supplies	100
Safety supplies	660
Total direct costs	$3,705
Total area of paint removed (sq ft)	1,338
Total cost/sq ft	$ 2.77

Table 17. Summary of Fort Hood wipe sample results.

Interior Location	Pre-Abatement Existing Dust	Post-Abatement Before Washing	Post-Abatement After Washing	Post-Abatement Washing Agent	Washing Agent Percent Reduction	Passed Clearance Standard
Laundry room floor	4.65	232.26	55.74	Pinesol	76%	Yes
Living room floor	46.45	55.74	9.29	Pinesol	83%	Yes
Bedroom #2 floor	9.29	74.32	27.87	Ledisolv	63%	Yes
Bedroom #3 floor	9.29	83.61	27.87	Ledisolv	67%	Yes
Living room floor	46.45	55.74	9.29	Mr. Clean	83%	Yes
Living room window	659.61	2053.16	222.97	Mr. Clean	89%	Yes
Bedroom #2 window	306.58	2155.35	445.93	TSP	79%	Yes

Notes:
1. Values are converted from μg/cm^2 to μgm/ft^2 for ease in comparing to EPA clearance levels for lead in dust and soil.
2. Samples from living room and bedroom #2 windows are assumed to be from window sills, which have a clearance level of 500 μg/ft^2.
3. Exercise caution in interpreting effectiveness of washing agents based on limited number of samples and unspecified wipe collection and analysis protocols.
4. Restrictions may apply to washing agents in areas accessible to young children.

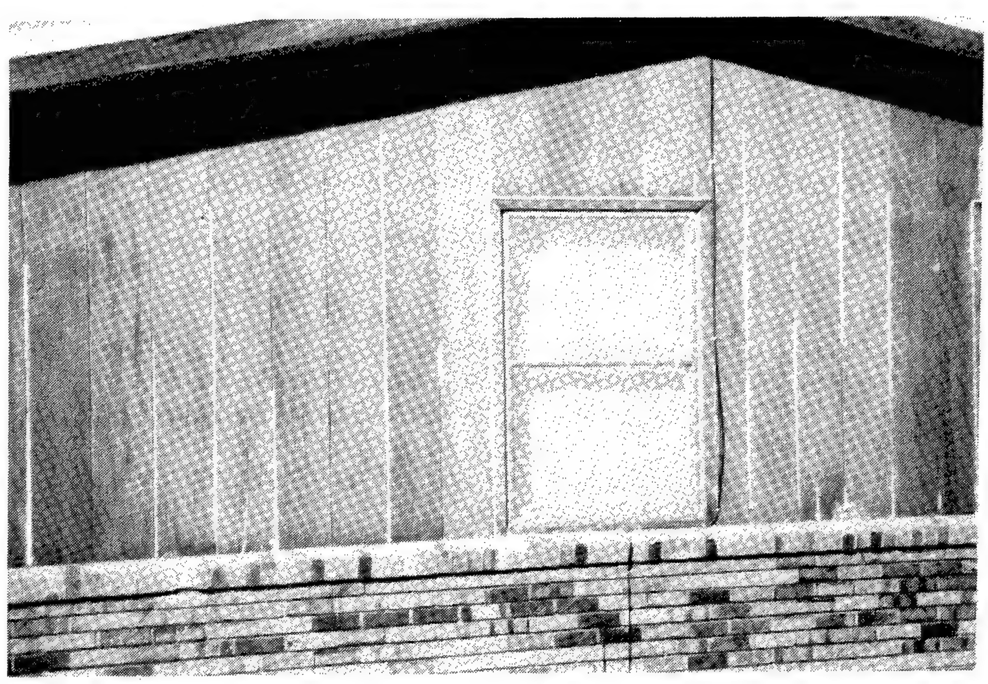

Figure 22. Fort Hood site with abatement completed and wood prepared for repainting.

Lead Paint Removal From Water Tanks at Fort Meade, MD

In the summer of 1994, the Directorate of Public Works at Fort Meade contracted to abate the LBP from the exterior surfaces of a 500,000-gal elevated water storage tank* (Figure 23). The paint was found to have 33 percent lead by weight. It was decided to use an engineered abrasive to remove the paint to generate a nonhazardous waste. It was necessary to use a 100 percent containment during abrasive blasting operations to prevent lead dust contamination of the surrounding site. The containment structure can be raised and lowered from ground level (Figure 24). Air monitoring of both the site and personnel was required, as was TCLP analysis of the chemically stabilized waste. The air-monitoring data (Table 18) show that lead levels outside the containment area did not exceed 30 $\mu g/m^3$ as established by 29 CFR 1910.1025. Figure 25 shows sections of the water tank after abrasive blasting and Figure 26 shows work in progress on the water tank supports.

The type of personal protective equipment used consisted of full-face supplied air respirators operated in the pressure demand mode, with a personal exposure limit of 100,000 $\mu g/m^3$. These criteria are taken from 29 CFR 1926.62 (f) (2) (I), Table 1. The representative data given in Table 18 show that the highest exposure level was less than 2000 $\mu g/m^3$. The TCLP results (Table 19) were all less than 5 mg/L. The waste was classified as nonhazardous.

* The contractor employed to sand-blast the water tank at Fort Meade was Snap Contracting Corporation, 5665 E. Va Beach Rd., Norfolk, VA 23502.

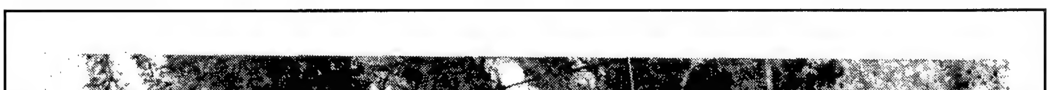

Figure 23. Water storage tank at Fort Meade (500,000-gal capacity).

Figure 24. Containment structure ready to be raised from ground level.

Table 18. Air monitoring for Fort Meade, Water Tank #8.

Sample	Type	Location	Flow Rate	Time Elapsed (min)	Air Collected (L)	Lead ($\mu g/m^3$)
02-01	Rem	40 ft downwind	3.4	455	1547	20.77
02-02	Rem	40 ft upwind	3.4	455	1547	< 3.23
02-03	Prs	Person 1	2.0	300	600	1955.42
02-04	Prs	Person 2	2.0	300	600	<6.33

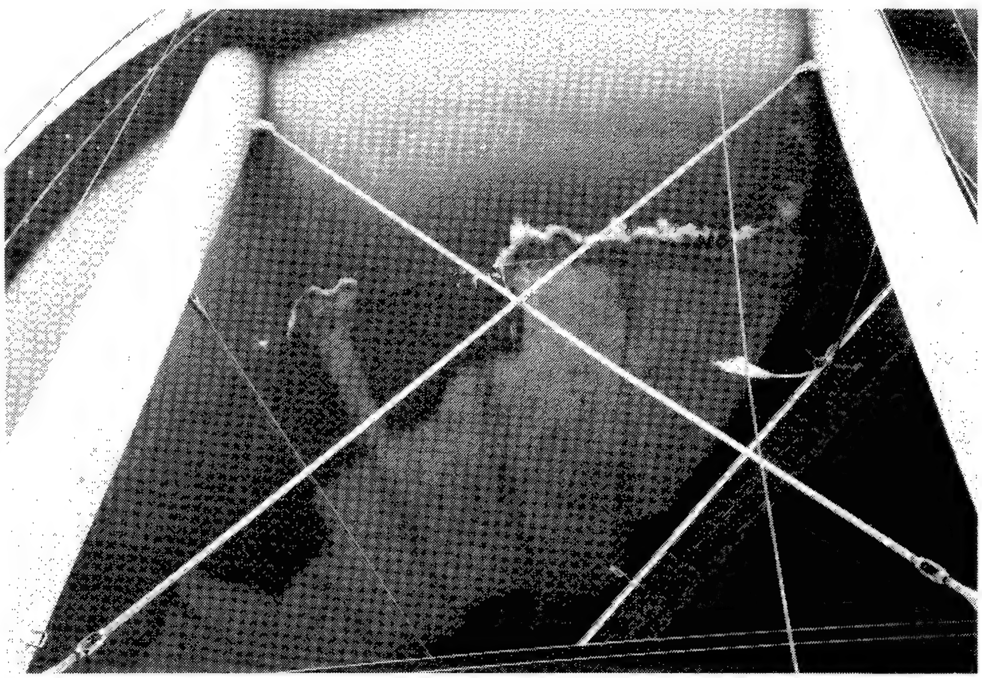

Figure 25. A section of the Fort Meade water tank that has been abrasive blasted.

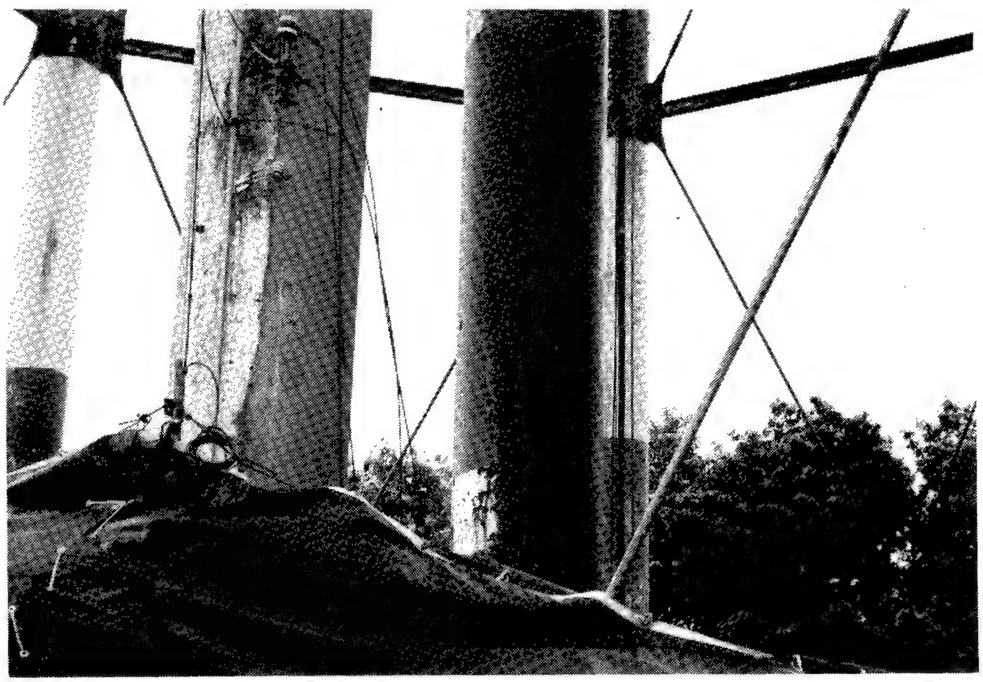

Figure 26. Work in progress on the water tank supports.

Table 19. TCLP results for Fort Meade, Water Tank #8.

Sample ID	TCLP Lead Result (mg/L)	TCLP Calcium Result (mg/L)
8	0.157	687
9	<0.1	698
10	<0.1	709
11	2.41	678
12	0.132	679
13	<0.1	757

5 Cost and Benefit Analysis

A cost analysis of the use of Blastox® as an additive to blast media to stabilize lead-based paint after removal was based on field data from actual test sites within the Army installation network. Further analysis based on life-cycle costs for other applications would be useful, but this study is limited to determination of present value savings, i.e., in immediate real dollar terms. It should be noted that the addition of Blastox® increases the cost of blasting media, but the additional cost is more than recovered by avoiding hazardous waste disposal costs.

The summary data (Tables 20 and 21) were derived from separate cost analyses of wood substrates and steel substrates where the lead-based paint was removed using an engineered abrasive. There is a variation in the equipment required for the various structures (i.e., one-story wood structures vs. 100-ft elevated steel tanks), thereby affecting contractor overhead and the amount of scaffolding used. Furthermore, both the amount of blast media per square foot and the rate of removal (sq ft/hour) vary depending on the type of substrate. Finally, the cost of Blastox® is affected by the recommended rate of mixture with conventional blast media, depending on the type of substrate.

Cost factors presented in the tables are based on actual contractor costs and are compared to actual government estimates from site specific lead-based paint abatement projects. Note that these costs are highly variable, and depend on local conditions; the following examples are intended to be taken as a guide. The term "capital facilities" refers to the capital investment in the technology (e.g., blast machines, nozzles, etc.). The labor figures include the personnel work expenditure for larger elevated structures and the associated scaffolding and dust containment. Consumables refers to the blast media, additives, tarps and covers, and packaging required for disposal. Environmental testing refers to required tests such as air monitoring (both personal and site), XRF testing, and TCLP waste analysis.

To determine the actual costs in terms of square-foot savings, the stripping rate, i.e., the rate of paint removal in square feet abated per hour, must also be included. Finally, the baseline disposal cost for the stabilized LBP waste must be compared to the hazardous waste disposal cost (i.e., the cost to be avoided).

In summary, the data given in Tables 20 and 21 show an immediate and relevant savings for either type of substrate using the addition of Blastox® to the blast media. The hazardous waste disposal cost avoidance ranges from \$0.12 to \$0.44/sq ft of abated surface for wood, and \$0.94 to \$3.06/sq ft for steel substrates.

Table 20. Savings in real present value dollars on wood substrates.

Cost Factors	Blast Media Without Blastox®	With Blastox® Additive at \$0.25 / lb (25% mixing)
Capital facilities[1]	\$7.14/site hour	\$7.14/site hour
Labor[2]	\$140.00/site hour	\$140.00/site hour
Consumables[3]	\$10.00/site hour	\$17.20/site hour
Environmental testing[4]	\$151.00	\$151.00
Subtotal	**\$308.14 / site hour**	**\$315.34/site hour**
Strip rate[5]	100 sq ft/hour	100 sq ft/hour
Removal cost	\$3.08/sq ft	\$3.15/sq ft
Disposal cost[6]	\$0.21 – \$0.54/sq ft (\$350 – \$900/ton)	\$0.02 – \$ 0.04/sq ft (\$35.21 – \$55.01/ton)
Total Cost	**\$3.29 – \$3.62 / sq. ft.**	**\$3.17 – \$3.19/sq ft**
Savings		**\$0.12 – \$0.43/sq ft**

Notes:
1. Capital rates of recovery are from actual contractor costs and DEH government cost estimate detail sheets. Costs for investment are amortized over 7 years for depreciation, and assume a 2000-hour site year.
2. Labor is quoted from actual contractor costs or derived from government estimate sheets.
3. Consumables are based on items used up in the job process. Blastox® is factored into this number based on its rate of application and percent of additive by weight. Abrasive blasting of wood required 1.2 lb of abrasive per sq ft of surface area blast cleaned.
4. Environmental testing includes air monitoring (both personal and site), XRF, and TCLP tests.
5. Strip rate varies depending on size of equipment and nature of the structure, i.e., wood buildings or 120-ft high elevated steel water or storage tank.
6. Disposal costs for hazardous waste were supplied by the Marketing Department, Chemical Waste Management, Inc., Oakbrook, IL. Costs for nonhazardous waste reflect typical costs from 12 states (*Solid Waste Digest*, October 1993, Chartwell Information Publishers, Inc., Alexandria, VA), and supplementary information from four additional states. The higher end of the range of disposal costs reflects per unit costs of the disposal of small quantities of waste (less than 5 tons). Lower per-unit disposal costs reflect disposal of bulk wastes from larger projects. Most projects involving abrasive blasting of wood will generate less than 5 tons of waste.

Table 21. Savings in real present value dollars on steel substrates.

Cost Factors	Blast Media Without Blastox®	With Blastox® Additive at $0.25/lb (20% mixing)
Capital Facilities[1]	$40.00/site hour	$40.00/site hour
Labor[2]	$280.00/site hour	$280.00/site hour
Consumables[3]	$70.00/site hour (containment) $67.00/site hour (crane rental) $137.00/site hour	$102.00/site hour $67.00/site hour $169.00/site hour
Environmental Testing[4]	$151.00	$151.00
Subtotal	**$608.00/site hour**	**$640.00/site hour**
Strip Rate[5]	100 sq ft/hour (may be higher when not hampered by height and configuration)	100 sq ft/hour
Removal Cost	$6.08/sq ft	$6.40/sq ft
Disposal Cost[6]	$1.40 – $3.60/sq ft ($350 – $900/ton)	$0.15 – $0.24/sq ft ($35.21 – $55.01/ton)
Total Cost	**$7.48 – $9.68/sq ft**	**$6.55 – $6.64/sq ft**
Savings		**$0.93 – $3.04/sq ft**

Notes:
1. Capital rates of recovery are from actual contractor costs and DEH government cost estimate detail sheets. Costs for investment are amortized over 7 years for depreciation, and assume a 2000-hour site year.
2. Labor is quoted from actual contractor costs or derived from government estimate sheets.
3. Consumables are based on items used up in the job process. Blastox® is factored into this number based on its rate of application and percent of additive by weight. Abrasive blasting of steel required 8 lb of abrasive per sq ft.
4. Environmental testing includes air monitoring (both personal and site), XRF, and TCLP tests.
5. Strip rate varies depending on size of equipment and nature of the structure, i.e., wood buildings or 120-ft high elevated steel water or storage tank.
6. Disposal costs for hazardous waste were supplied by the Marketing Department, Chemical Waste Management, Inc., Oakbrook, IL. Costs for nonhazardous waste reflect typical costs from 12 states (*Solid Waste Digest*, October 1993, Chartwell Information Publishers, Inc., Alexandria, VA), and supplementary information from four additional states. The higher end of the range of disposal costs reflects per unit costs of the disposal of small quantities of waste (less than 5 tons). Lower per-unit disposal costs reflect disposal of bulk wastes from larger projects.

6 Discussion of Waste Classification

The results of the USACERL research indicate that Blastox (a calcium silicate-based cementitious material), when used according to the recommendations of this report, reduces the leachability of lead to a level below the regulatory standard of 5 ppm. The additive, which is similar in composition to Portland cement, is based on cement stabilization, a "Best Demonstrated Available Technology" (BDAT) recommended by the USEPA.

Before water is introduced and the cementitious reaction is completed, the lead in the waste material is not yet stabilized (Boy 1996). Appropriate safeguards must be taken to avoid release of unstabilized lead during handling. In addition to liabilities under hazardous waste regulations, a generator may be held liable under the Comprehensive Emergency Response Compensation and Liability Act (CERCLA) for any environmental damages caused by the release of heavy metals into the environment.

Waste classification is the full legal responsibility of the generator, and is based on either: (1) testing the waste according to the methods set forth in Subpart C of 40 CFR Part 261, or (2) applying knowledge of the hazardous characteristics of the waste in light of the materials or the process used. Waste from steel structure depainting may contain hazardous constituents such as cadmium or chromium, in addition to lead.

Some states have enacted regulations that are more restrictive than RCRA. For example, the State of California regulates lead wastes based on total lead content, in addition to leachable lead. Some States may also regulate lead-containing waste under solid waste regulations (even though the waste is not classified as "hazardous"). USACERL recommends that before engineering personnel select Blastox for use, engineers, contracting personnel, regulators having jurisdiction, and available landfill operators should meet and agree to accept Blastox and to accept associated testing and handling procedures to ensure disposal of lead-based paint waste as nonhazardous waste when using Blastox.

USACERL submitted a draft of this report to the USEPA for review. Copies of the USACERL letter and the USEPA's response are attached in the Appendix to this report.

7 Conclusions and Recommendations

Conclusions

This study evaluated the composition, performance, and cost-effectiveness of using an engineered abrasive containing Blastox® for LBP removal from wood and metal structures, and concludes that:

1. X-ray diffraction, x-ray fluorescence, energy dispersive spectroscopy, and scanning electron microscopy studies determined that Blastox® is a di- and tri-calcium silicate-based material similar in chemical composition to Type I cement. Cements are known to stabilize lead by the formation of insoluble lead silicates.

2. The use of a proprietary chemical stabilizer, Blastox®, combined with an abrasive coal slag blasting media removed lead-based paint from exterior surfaces of wood structures at Fort Meade, Fort Carson, and Fort Hood. The surfaces were rendered lead hazard-free and suitable for repainting.

3. Elevated steel water storage tanks at Fort Meade were also abrasive-blasted with an engineered abrasive containing Blastox®. The steel surfaces were finished to near white grade and were found to be lead-free and suitable for repainting.

4. The blasting waste containing the paint debris from all the wood and steel structures abrasive blasted at the three installations leached less than 5 ppm lead when tested using the Toxicity Characteristic Leaching Procedure (TCLP, USEPA Method 1311), and therefore did not exhibit the RCRA toxicity characteristic for lead.

5. No significant reactions were found to occur between the lead and Blastox® particles during the dry abrasive blasting process. The process through which the lead is stabilized occurs when water is added to the material by the generator, or during the weathering of the sample (wetting in a landfill environment).

6. The long-term stability of the paint waste to leaching was determined by TCLP (USEPA Method 1311), back-to-back TCLP, and MEP (USEPA Method 1320) analyses. No detectable lead was found even after the pH buffering effect had been eliminated in 10 extraction cycles.

7. The savings in the cost of disposal of the blasting waste are estimated to be \$0.12 to \$0.43 per sq ft of abated surface for wood structures and \$0.93 to \$3.04 per sq ft for steel structures. These savings are due to the substantial reduction in disposal costs for a nonhazardous waste.

Recommendations

1. It is recommended that an engineered abrasive containing Blastox or its equivalent be considered as a feasible alternative to other means of removal (e.g., traditional abrasives, handtool cleaning, or chemical strippers) on a job-by-job basis when LBP must be removed from wood or steel structures.

2. USACERL recommends that, before engineering personnel select Blastox for use, engineers, contracting personnel, regulators having jurisdiction, and available landfill operators should meet and agree on the methodology and that the waste stream generated meets the standards set for nonhazardous waste as defined by the USEPA, State, and agency regulators.

3. If Blastox® is to be mixed with the abrasive media in the field, steps must be taken to ensure that mixing is complete at the recommended rate. If mixing is incomplete or too little Blastox® is used, a hazardous waste may be produced when the abrasive is used to remove LBP. The preferred option is purchase of premixed abrasives.

4. When used to remove paint from wood structures, a minimum of 25 weight percent of the chemical stabilizer, Blastox®, should be added to the abrasive blast media.

5. When used to remove paint from steel structures, a minimum of 20 weight percent of the chemical stabilizer, Blastox®, should be added to the abrasive blast media.

6. Similar to cement, water needs to be added to the engineered abrasive/paint waste mixture to initiate the cementitious reaction. Water should be added at a ratio of about 1 part water for every 2 parts of Blastox, and thoroughly mixed.

7. The testing of the chemically stabilized lead-based paint waste should include the TCLP (USEPA Method 1311) analysis.

8. Additional research to elucidate the basic mechanism of lead stabilization in a silicate matrix is recommended.

References

Akhter, H., L. Butler, S. Branz, F. Cartledge, and M. Tittlebaum, "Immobilization of As, Cd, Cr, and Pb-Containing Soils by Using Cement of Pozzolanic Fixing Agents," *Journal of Hazardous Materials*, vol 24 (1990), pp 145-155.

Bhatty, J, and P. West "Interaction of Heavy Metals in Portland Cement Stabilized Waste Systems: Effects on Paste Hydration," *Proceedings of the Emerging Technologies Symposium on Cement and Concrete in the Global Environments* (Chicago, IL, 10-11 March 1993), pp 1-22.

Bishop, L., "Leaching of Inorganic Hazardous Constituents for Stabilized/Solidified Hazardous Waste," *Hazardous Waste and Hazardous Materials*, vol 5 (1988), pp 129-143.

Boy, J.H., T.D. Race, K.A. Reinbold, Technical Report (TR) 96/51 (U.S. Army Construction Engineering Research Laboratories [USACERL], February 1996).

Boy, J.H., T.D. Race, K.A. Reinbold, J. Bukowski, and X. Zhu, "Stabilization of Metal Contaminated Paint Removal Waste in Cementitious Matrix Containing Blast Furnace Slag," *Proceedings of the 87th Annual Air & Waste Management Conference* (Cincinnati, OH, June 1994).

Code of the Federal Regulations (CFR), title 14, parts 240, section 4.

CFR, title 16, part 1303, sections 8, 9, and 86.

Conner, J., *Chemical Fixation and Solidification of Hazardous Wastes* (Van Nostrand Reinhold, New York, 1990), pp 130-139.

Cullinane, Jr., M., L. Jones, and P. Malone, *Handbook for Stabilization / Solidification of Hazardous Wastes* (Hazardous Waste Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency [USEPA], Cincinnati, OH, 1986), pp 2.21 - 2.24.

Federal Specification TT-P-104b, *Paint (White Lead and Oil, Exterior, Ready-Mixed, White and Light Tints)* (Federal Supply Services, General Services Administration, Washington, DC, 16 April 1965), pp 1-5.

Komarneni, S., "Heavy Metal Removal from Aqueous Solutions by Tobermorites and Zeolites," *Nuclear and Chemical Waste Management*, vol 5 (1985), pp 247-250.

Komarneni, S., D. Roy, and R. Roy, "Al-Substituted Tobermorite: Shows Calcium Exchange," *Cement and Concrete Research*, vol 12 (1982), pp 773-780.

Komarneni, S., E. Breval, D. Roy, and R. Roy, "Reactions of Some Calcium Silicates With Metal Cations," *Cement and Concrete Research*, vol 18 (1988), pp 204-220.

U.S. Army Environmental Hygiene Agency, *Sampling Protocol: Building Demolition Debris and Buildings Painted With Lead-Based Paint* (U.S. Army Environmental Hygiene Agency Waste Disposal Engineering Division, Aberdeen Proving Ground, MD, 1993).

U.S. Environmental Protection Agency Method 1320, "Extraction Procedure, Multiple, for Delisting," *Federal Register*, vol 54, No. 188 (29 September 1989), p 40262.

U.S. Environmental Protection Agency Method 1311, "Toxicity Characteristic Leaching Procedure," 40 CFR Part 261, *Federal Register*, vol 55, No. 61 (29 March 1990).

U.S. Environmental Protection Agency SW-846, *Test Methods for Evaluating Solid Waste—Physical / Chemical Methods*, 3d ed. (Office of Solid Waste, Emergency Response, Washington DC, November 1986).

Appendix: Correspondence Between USACERL and the USEPA

Materials Science & Technology Division

U.S. Environmental Protection Agency
Mr. Richard Kinch, Chief
Waste Treatment Branch
401 M Street, S.W.
Mail Code 5302W
Washington, DC 20460

Dear Mr. Kinch:

Reference correspondence from Mr. Kenneth B. Rota, U.S. EPA New England Region, to the undersigned, dated May 9, 1995.

As explained in the attached correspondence, our office has investigated a proprietary product, Blastox®, which chemically stabilizes debris generated during the abrasive blast removal of lead-based paint. Blastox® is a dry granular material that has a chemical composition and properties similar to portland cement. It is added to traditional sandblast abrasives at a rate of 20 to 25% by weight. The U.S. Army Construction Engineering Research Laboratories (USACERL) demonstrated the use of this product in lead paint removal projects at several Army installations. In each case the resultant waste leached lead at a rate of less than five parts per million when tested in accordance with the toxicity characteristic leaching procedure (TCLP).

Our laboratory also conducted an investigation of the mechanism of the fixation of lead that occurs with Blastox®. We found no evidence that the product reacts in the dry state to stabilize the lead in the waste. Based on the laboratory data, we concluded that the stabilization reaction occurs in the wet state, during the TCLP test or when the material otherwise comes in contact with water to initiate a hydration reaction. A copy of the draft USACERL report is attached.

Army environmental reviewers of the draft report have expressed concern about the interpretation of TCLP results of waste generated during blasting with an abrasive incorporating Blastox®. In addition, there is some concern over the need to wet the waste prior to disposal to initiate the hydration reaction. If wetting is deemed necessary, is this considered hazardous waste treatment requiring a permit? As Mr. Rota suggested in his letter, we are contacting your office to seek an interpretation of the regulatory status of this product.

-2-

If I can be of any assistance, I may be contacted at (217) 373-6753. I look forward to your response.

Sincerely,

Vincent F. Hock
Principal Investigator

Copies Furnished:

Susan Drozdz
Ken Rota

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

AUG 16 1995

OFFICE OF
SOLID WASTE AND EMERGENCY
RESPONSE

Mr. Vincent F. Hock, Metallurgist
U.S. Army Corp of Engineers
Construction Engineering Research Laboratories
P.O. Box 9005
Champaign, IL 61826-9005

Dear Mr. Hock:

Thanks for your letter dated May 9, 1995 regarding the use of Blastox, a product that is added to sandblast abrasives and stabilizes waste generated from the abrasive blast removal of lead-based paint. In addition, I have reviewed your correspondence with Kenneth Rota of EPA Region I, who initially sent a response to your questions concerning the product. EPA's views on the regulatory status of paint chips containing Blastox is set out below.

It is my understanding that Blastox is a dry granular additive similar to portland cement. Stabilization of the lead in the paint chips occurs only in the wet state--during the TCLP test, or when the material comes into contact with water. You have asked whether the addition of water to initiate the hydration reaction considered hazardous waste treatment requiring a permit?

In EPA's view, adding water to the mixture of paint chips and Blastox would require a permit only if the mixture is a regulated hazardous waste. You have told us that the Blastox material and paint material mix in the process that generates the paint chip waste. EPA, consequently, considers it appropriate to perform TCLP testing on the mixture. EPA would not consider the addition of water for the purpose of using the TCLP test method to be hazardous waste treatment, as the waste would not yet have been classified as hazardous waste. If samples of the mixture failed to exhibit the Toxicity Characteristic, the mixture could be managed as non-hazardous waste, and any subsequent stabilization could be conducted without a permit.

If, however, a representative sample from the paint chip waste exhibits any characteristic of hazardous waste (e.g., TC for lead), then subsequent activities such as the addition of water

for stabilization purposes would meet the definition of treatment under 40 CFR 260.10. You should note that the federal hazardous waste regulations allow generators to treat and/or store hazardous waste in accumulation tanks or containers, without a RCRA permit, as provided in 40 CFR 262.34 (including compliance with land disposal restriction standards in 268.7(a)(4)). You should also note that specific hazardous waste requirements in States authorized to implement the RCRA program can be more stringent than the federal requirements.

If we can of further assistance to you, please do not hesitate to call myself or Doug Heimlich of my staff at (703) 308-8489.

Sincerely,

Richard Kinch
Chief
Waste Treatment Branch

cc:
Mr. Kenneth B. Rota (EPA Region 1)

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